Volume 30, No. 1
January, 1960

JOURNAL OF GENERAL CHEMISTRY of the USSR

ЖУРНАЛ ОБЩЕЙ ХИМИИ
(ZHURNAL OBSHCHEI KHIMII)

TRANSLATED FROM RUSSIAN

CONSULTANTS BUREAU

Volume 30, No. 1

January, 1960

JOURNAL OF GENERAL CHEMISTRY OF THE USSR

(ZHURNAL OBSHCHEI KHIMII)

A publication of the Academy of Sciences of the USSR

IN ENGLISH TRANSLATION

Year and issue of first translation:
Vol. 19 No. 1 January 1949

	U. S. and Canada	*Foreign*
Annual Subscription	*$120.00*	*$125.00*
Annual subscription for libraries of nonprofit academic institutions	*50.00*	*55.00*
Single issue	*10.00*	*10.00*

CONSULTANTS BUREAU ENTERPRISES, INC.
227 West 17th Street, New York, N. Y.

Volume 30, No. 1
January, 1960

JOURNAL OF GENERAL CHEMISTRY OF THE USSR

(ZHURNAL OBSHCHEI KHIMII)

A publication of the Academy of Sciences of the USSR

IN ENGLISH TRANSLATION

Year and issue of first translation:
Vol. 19 No. 1 January 1949

	U. S. and Canada	*Foreign*
Annual Subscription	*$120.00*	*$125.00*
Annual subscription for libraries of nonprofit academic institutions	*50.00*	*55.00*
Single issue	*10.00*	*10.00*

CONSULTANTS BUREAU ENTERPRISES, INC.
227 West 17th Street, New York, N. Y.

JOURNAL OF GENERAL CHEMISTRY OF THE USSR

Volume 30, Number 1 January, 1960

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

FORMS OF THE HIGHER OXIDES OF VANADIUM AS JUDGED FROM THEIR ELECTRICAL CONDUCTIVITY

N. I. Bogdanova and S. M. Ariya

Leningrad State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 3-7, January, 1960

Original article submitted January 12, 1959

The question of the forms (composition) of chemical compounds is related to a number of the most important problems of general chemistry. As a result of the broadening scope of experimental methods of investigation and the continuous perfection of such methods, particularly of the X-ray method, the presence of series of discrete "mixed" compounds has been indicated in recent years in a whole group of binary systems (by "mixed" compounds we mean those whose composition does not correspond to any one whole-number value for the valence of the metal and whose lattice apparently contains atoms of the metal in various valence states). Among such systems we may point out the system V – O, in the course of an X-ray investigation of which Anderson [1] concluded that in the range of compositions $VO_{1.5}$ - VO_2 the following discrete "mixed" compounds existed: $VO_{1.67}$, $VO_{1.75}$, $VO_{1.80}$, $VO_{1.84}$, $VO_{1.86}$, and $VO_{1.87}$. These results were confirmed by Burdese [2]. Aebi [3], who investigated by the X-ray method the region $VO_{2.0}$ - $VO_{2.5}$, established the existence of the compound $VO_{2.17}$. An earlier X-ray and magnetochemical investigation of the oxides of vanadium [4] and an investigation of their electrical conductivity [5] led to the conclusion that in the region $VO_{1.5}$ - $VO_{2.5}$ the following phases exist: a γ-phase with the upper boundary of its area of homogeneity at the composition $VO_{1.5}$, a β-phase $VO_{1.67}$ - $VO_{1.79}$, an α-phase $VO_{1.71}$ - $VO_{2.00}$, and an α'-phase $VO_{2.00}$ - $VO_{2.23}$. M. A. Gurevich and B. F. Ormont [6] concluded that for $VO_{1.5}$ an area of homogeneity exists that extends in the direction of a higher oxygen content (these authors supposedly showed an upper limit corresponding to the composition $VO_{1.70}$).

Taking into consideration the fact that the information on the composition of the "mixed" compounds in the system V – O had mainly been obtained only on the basis of X-ray data and that there were several contradictions in the data of the various authors, and in view of the importance of the question of the forms of the discrete mixed compounds, we undertook a study of electrical conductivity in the system $VO_{1.5}$ - $VO_{2.0}$ in order to be able to judge on the basis of another method of investigation. Furthermore, it was of considerable interest to ascertain the type of relationship of different properties (including electrical conductivity) to the composition in systems with many discrete compounds of closely similar composition. The oxides of vanadium were prepared from especially pure "two-five" oxide of vanadium [V_2O_5] containing, according to its spectral analysis, only thousandths of a percent of impurities.

Part of the V_2O_5 was carefully reduced with purified electrolytic hydrogen at gradually increasing temperature (up to 900°) to V_2O_3. The composition of the reduction product corresponded to the formula $VO_{1.515}$. Preparations of the composition $VO_{1.515}$ - VO_2 were obtained by heating mixtures of V_2O_3 and V_2O_5 of the appropriate composition in vacuo. The carefully ground mixture was heated first at 700° (for 10 hours) and then at 900° (for 20 hours). After this the preparations were again ground and pressed under a pressure of about 10,000 kg/cm^2 into tablets, which were heated in a high-vacuum high-frequency furnace at 1600° for 1.5 hours.

The electrical conductivity was measured with a potentiometer in high vacuum in the range 20-600° (at 10° intervals). The details of the method of measurement have been described by us previously [7].

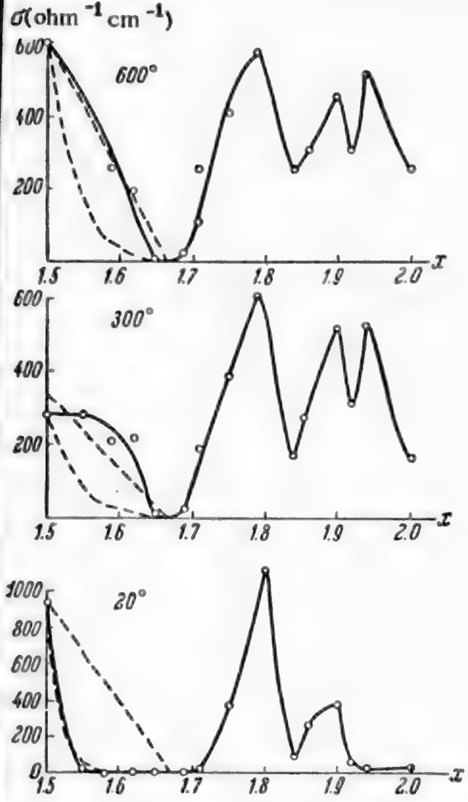


Fig. 1. Relation of specific electrical conductivity of oxides of vanadium (σ) to their composition (the region in which values of σ for mixtures $VO_{1.50}$ and $VO_{1.67}$ should lie is bounded by broken lines [9]).

The composition of the preparations was established by determining the increase in weight upon oxidation to V_2O_5, which was accomplished by heating to constant weight at 600-700°.

The reproducibility of the measurements was satisfactory, as can be seen from Table 1.

The relation of the electrical conductivity to the composition at 20, 300, and 600° is shown in Fig. 1. The special points on the σ-composition curves at these temperatures correspond to the compositions $VO_{1.67}$, $VO_{1.80}$, and $VO_{1.84}$, and in addition lie in the region $VO_{1.90}$ - $VO_{1.94}$, which does not contradict the data of Anderson on the existence of discrete compounds of the composition $VO_{1.67}$, $VO_{1.80}$, and $VO_{1.84}$.

The relationship of electrical conductivity to temperature for oxides of different composition is given in Fig. 2. It is clear from this figure that for the oxides of the compositions $VO_{1.55}$, $VO_{1.58}$, $VO_{1.65}$, $VO_{1.69}$, and $VO_{1.71}$ there is a rapid increase in electrical conductivity at approximately 160°. With the composition $VO_{1.515}$ this jump does not occur. The electrical conductivity for the compositions $VO_{1.515}$ - $VO_{1.67}$ is included within the range of values in which the conductivities for the mechanical mixtures $VO_{1.515}$ and $VO_{1.67}$ may be found. The fact that the rapid change in electrical conductivity takes place for all the oxides mentioned above at the same temperature indicates that the region $VO_{1.515}$ - $VO_{1.67}$ contained two phases and the conversion at approximately 160° which is expressed in the rapid increase in conductivity should be ascribed to the compound $VO_{1.67}$. Actually, it is difficult to conceive that if the range $VO_{1.5}$ - $VO_{1.67}$ corresponded to a region of homogeneity, i.e., to some solid solution, the conversion temperature would not be shifted with a change in composition. A preliminary thermodynamic investigation of the equilibrium of the oxides of vanadium with CO_2/CO mixtures, which we carried out with Yu. G. Popov, also showed that the range $VO_{1.51}$ - $VO_{1.67}$ corresponds to a two-phase region in the system V – O.

TABLE 1

Composition of oxide	Electrical conductivity (in ohms^{-1} cm^{-1}) at 20°	
	tablet 1	tablet 2
$VO_{1.90}$	312	325
$VO_{2.0}$	34	29
$VO_{1.65}$	0.1058	0.0552

On the σ-composition curves there is no special point at the composition $VO_{1.75}$, but the conversion at 160° is absent in the oxide of this composition, which indicates that it is not a mixture of $VO_{1.67}$ and an oxide of higher oxygen content. The fact that the form of the relationship between electrical conductivity and temperature for the composition $VO_{1.79}$ differs distinctly from that for the composition $VO_{1.75}$ (Fig. 2) confirms the statement by Anderson that a compound of this composition exists. If it has a region of homogeneity, this is rather small.

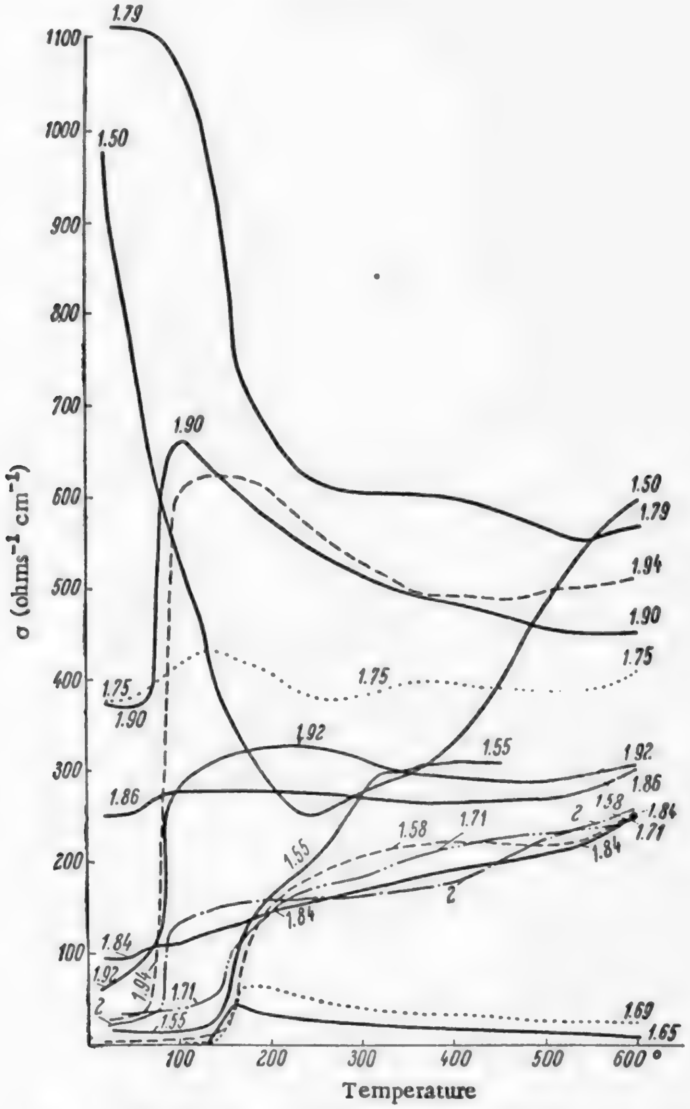


Fig. 2. Relationship of specific electrical conductivity of oxides of vanadium to temperature.

For the composition range $VO_{1.88}$ - $VO_{2.00}$ there is a characteristic conversion at 80° which appears as a sharp increase in electrical conductivity. The constancy of the temperature of conversion with a change in composition in this range indicates that at room temperature the region $VO_{1.88}$ - $VO_{2.00}$ contains two phases. However, there is a maximum in the σ-composition curve at 20° for the composition $VO_{1.90}$, and at higher temperatures special points appear for the compositions $VO_{1.92}$ and $VO_{1.94}$. It is possible that their appearance can be explained by the fact that the preparations of the compositions $VO_{1.9}$ - $VO_{2.0}$ were obtained on sintering in rather porous form, which made the measurements much less accurate. It is also possible that the rise in temperature

is caused by the complication of the phase relationships in this region of the system V—O. It is appropriate in this connection to note that Anderson [1] observed lines in the X-ray diagrams of preparations of the composition $VO_{1.88}$ - $VO_{2.00}$ that do not belong to $VO_{1.87}$ and $VO_{2.00}$ and indicate the existence of some phases in this composition range.

The data that we obtained on the electrical conductivity of the oxides of vanadium agree with the data of Anderson [1] with respect to the existence of the compound $VO_{1.84}$: a minimum in the σ-composition curve corresponds to this composition, and furthermore the transition from $VO_{1.79}$ to $VO_{1.84}$ is marked by a distinct change in the form of the relationship between electrical conductivity and temperature.

It is of essential importance that the rapid increase in electrical conductivity at 80°, which is still easily noticeable for the composition $VO_{1.93}$ (Fig. 2), is absent in the oxide $VO_{1.88}$; thus, it is indicated that at low temperatures it is not a mixture of $VO_{2.00}$ and some other oxide that corresponds to this composition. In other words, our data show that in the range $VO_{1.84}$ - $VO_{1.88}$ there is some compound, or perhaps the two compounds indicated by Anderson [1].

However, it is difficult to establish their composition from electrical conductivity data, since the latter property (especially for objects that are not monocrystalline) cannot be measured accurately enough. An increase in the number of compositions studied in the region $VO_{1.84}$ - $VO_{1.88}$ could scarcely help in the establishment of the phase relationships within it.

Our data on the electrical conductivity of the oxide of vanadium are in satisfactory agreement with the results of the investigations of Klemm and Pirscher [5] (these authors made measurements only at room temperature): the form of the relationship of the electrical conductivity to the composition obtained by us differs from that given by Klemm and Pirscher in having a special point at the composition $VO_{1.84}$. The absolute value of the electrical conductivity of $VO_{2.00}$ at room temperature obtained by us is substantially higher than that found by Rüdorff, Walter, and Stadtler [8], which is explained, apparently, by the fact that these authors used preparations pressed in the cold instead of heated.

We have established previously that the electrical conductivity of titanous oxide, $TiO_{1.00}$ - $TiO_{1.20}$, does not differ to any practical extent from that of a mixture of $TiO_{1.00}$ and $TiO_{1.50}$ [7]. It is pertinent in this connection to note that the electrical conductivity of discrete "mixed" compounds in the range $VO_{1.5}$ - $VO_{2.0}$ differs from that of a mixture of these oxides, although in the lattices of the discrete "mixed" compounds there are vanadium atoms in two different valent states. It is apparent that the equality of the electrical conductivity established in the case of titanous oxide for substances lying within the limits of the region of homogeneity and of the electrical conductivity of the corresponding mixture is not the result of the existence of Ti^{II} and Ti^{III} in its lattice (i.e., atoms of titanium in the same valent states as figure in TiO and Ti_2O_3), but is explained by special structural peculiarities of the oxides of variable composition.

SUMMARY

The existence of the "mixed" compounds $VO_{1.67}$, $VO_{1.75}$, $VO_{1.80}$ and $VO_{1.84}$ has been confirmed by investigation of the electrical conductivity of the oxides of vanadium, and data also have been obtained on the existence of compounds in the range $VO_{1.84}$ - $VO_{1.88}$. The composition of these compounds requires further, more accurate definition.

LITERATURE CITED

[1] G. Andersson, Acta Chem. Scand. 8, 1599 (1954).

[2] A. Burdese, Ann. chimica 47, 785 (1957).

[3] F. Aebi, Helv. Chim. Acta 31, 8 (1948).

[4] W. Klemm and E. Hoschek, Z. anorg. allg. Chem. 226, 359 (1936); 242, 63 (1939).

[5] W. Klemm and P. Pirscher, Optik 3, 75 (1948).

[6] M. A. Gurevich and B. F. Ormont, Zhur. Neorg. Khim. 2, 2581 (1957).

[7] S. M. Ariya and N. I. Bogdanova, Zhur. Fiz. Tverd. Tela 1, 1022 (1959).

[8] W. Rüdorff, G. Walter, and J. Stadler, Z. anorg. allg. Chem. 297, 1 (1958).

STRUCTURAL DIAGRAMS OF TERNARY LIQUID SYSTEMS CONTAINING TWO BINARY STRATIFICATIONS WITH LOWER CRITICAL TEMPERATURES OF SOLUTION. I.

E. F. Zhuravlev

Perm State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 7-12, January, 1960

Original article submitted December 22, 1958

Ternary liquid systems having two binary stratifications with upper critical temperatures of solution yield several types of structural diagrams differing in principle.

The difference in the geometrical form of the region of stratification, as has been shown by R. V. Mertslin [1], V. F. Ust'-Kachkintsev [2], E. F. Zhuravlev [3], and K. I. Mochalov [4], and also recently by I. L. Krupatkin [5], is inseparably connected with the physicochemical reaction of the components of the third binary homogeneous system that forms a constituent part of the ternary system. As proposed by R. V. Mertslin [6], such a binary system is called the prevailing system. The highly developed chemical reaction of the components of the prevailing system, which is characterized by the existence in it of thermally undissociated compounds in the liquid phase, results in the formation in the region of stratification of a ternary system of elements of singularity in the form of anticlinal or synclinal folds.

Investigation of the prevailing system and application of the general principles of physicochemical analysis permitted the above-mentioned authors to realize in a comparatively short time almost all of the theoretically conceivable types of structural diagrams of ternary liquid systems, even such as could not be predicted by the purely geometrical concept of Schreinemachers.

In contrast with this, ternary systems having within the boundary contour binary systems with lower critical temperatures of solution have been only slightly studied theoretically and experimentally. Beginning with the work of Schreinemachers and up to the present time, there has existed in the theory of heterogeneous equilibria the general opinion that the geometrical forms of the surface of the two-phase liquid state are identical for systems with upper and lower critical temperatures of solution; they differ only in their order of temperature. This point of view was developed in the work of V. F. Ust'-Kachkintsev [2], who added a study of singular diagrams to the theory of ternary stratifying systems.

In the present investigation, we set up for ourselves the goal of deducing the possible types of structural diagrams for ternary liquid systems having within the boundary contour two stratifying binary systems with lower critical temperatures of solution or with a closed region of stratification.

Let us imagine a ternary system $A-B-C$ consisting of two limited systems $A-C$ and $B-C$ with a discontinuity in the solubility of the liquid phases and a third system $A-B$ which is homogeneous. The components of the homogeneous system may be characterized by various physicochemical relationships. These relationships may be normal or may lead to disruption of the molecules of the components or to their chemical reaction. In their turn, the chemical compounds formed by reaction of the components may be thermally dissociated or undissociated in the liquid phase. The interrelations of the components of the homogeneous system

will certainly exert a certain influence on the character of the mutual solubility of the liquid phases and, consequently, on the geometrical form of the region of stratification of the ternary system. However, we must also take into consideration the physicochemical relation of the components of the limited stratifying systems, inasmuch as we are considering systems with lower critical temperatures of solution.*

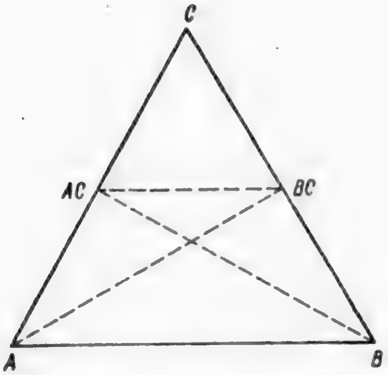


Fig. 1. Geometrical representation of the reaction of exchange displacement in ternary systems.

In this communication we shall consider only those ternary systems in which the limited homogeneous system A – B is characterized by normal relationships of the components.

With such limitations, in the given ternary system A – B – C (Fig. 1) the qualitative differences in the possible structural diagrams are determined by the position of the equilibrium of the three reversible chemical processes: $A + C \rightleftharpoons AC$, $B + C \rightleftharpoons BC$, and $AC + B \rightleftharpoons BC + A$.

The first two equations express the chemical reaction of the components of the limited stratifying systems. Both processes, with an increase in temperature, shift in the reverse direction, which in the final result leads to stratification of the systems A – C and B – C. The third equation corresponds to the reaction of mutual displacement. Actually, in any ternary system where two components (A and B) form chemical compounds (AC and BC) with the third one (C), the reaction indicated above must occur. The geometrical representation of the reaction of mutual displacement is the trapezium (A – AC – BC – B) with its two diagonals intersecting in some point. Each of the diagonals may be stable under certain conditions.

If the labile equilibrium is shifted appreciably in a straight line, then the line A – BC becomes the stable diagonal. It bears on the limited system B – C, which obviously will play the prevailing role in relation to the two other limited systems (A – C and A – B). On the other hand, when the equilibrium is strongly shifted in the reverse direction, then the line B – AC will be the stable diagonal. It bears on the side A – C, which takes on the same physical significance as did the side B – C of the triangle in the previous case. A judgment as to the stable diagonal, and consequently as to the prevailing binary system, can be obtained by comparison of the temperatures at which the critical points of the stratifying limited systems lie. The more these temperatures differ, the more distinctly will the prevailing effect of the limited system in which the temperature is higher be expressed. In the case where the equilibrium of the reaction of exchange displacement is not shifted appreciably in either direction, there are grounds for equal stability of the diagonals, and also for the simultaneous existence of two prevailing limited systems. The two limited systems A – C and B – C have equal claims on each other. This exceptional phenomenon can occur only in ternary systems in which the lower critical points of the limited systems with stratification lie at the same or very close temperatures.

We have directed attention above to the fact that the first two equations describe reversible chemical processes. Under conditions where they are completely shifted in the reverse direction, the physical meaning of the third equation is lost. In the ternary system, a reciprocal displacement cannot exist. The stratifying binary systems lose their prevailing significance. The homogeneous system A – B takes on this role.

In accordance with what has been said above, we should expect three different principal types of structural diagrams for ternary systems.

<u>Type 1a.</u> In the ternary system A – B – C let the critical temperature of stratification in the limited system A – C be higher than in the system B – C. Under such conditions, stratification arises in the ternary system at the critical point of the limited system B – C, in which the necessary temperature conditions are first set up for an appreciable shift of the mobile equilibrium $BC \rightarrow B + C$. A rise in temperature will favor a further shift of this equilibrium and consequently, the development of a two-phase liquid region within the composition

* It is considered to be generally acknowledged that binary systems with a closed region of stratification, and also the particular case of systems with a lower critical temperature of solution, are the result of chemical reaction of the components.

triangle of the system. Since in the temperature range between the critical points of the stratifying systems the systems A − C and A − B are homogeneous, the isotherms of the region of stratification with their binodals will bear on the limited system B − C and will converge in the ternary critical points. The prevailing one of the two homogeneous systems under the given conditions will be the system A − C, since the existence in it of a lower critical temperature of solution is the result of chemical reaction of the components. The nodes of the isotherms of the region of stratification, especially for low temperatures, should be appreciably displaced in the direction of this system.

A further elevation of the temperature leads to a widening of the discontinuity in solubility, caused not only by a decrease in mutual solubility in the system B − C, but also by the appearance of conditions for stratification in the system A − C. The binodal curve, shifting in the direction of A − C, coincides in its ternary critical point with the critical point of the region of stratification of this binary system. At temperatures higher than the critical temperature of solution in the system A − C the isotherms of the region of stratification will consist of two independent lines connecting saturated solutions of limited stratification. At the same time, the prevailing effect of the system A − C on the region of stratification is diminished. Gradually, the homogeneous system A − B takes over this role. Gradually, also the nodes of the isotherms of the region of stratification are unfolded, and at temperatures above the two critical points they diverge as a fanlike cluster in the direction of the homogeneous system A − B.

The simultaneous existence of two prevailing systems and the continuous transition of prevalence from one limited system to the other with a change in the temperature factor also leads to a continuous change in the isotherms of the region of stratification and the lines of the ternary critical points. The general appearance of the structural diagram of such a system is shown in Fig. 2a.

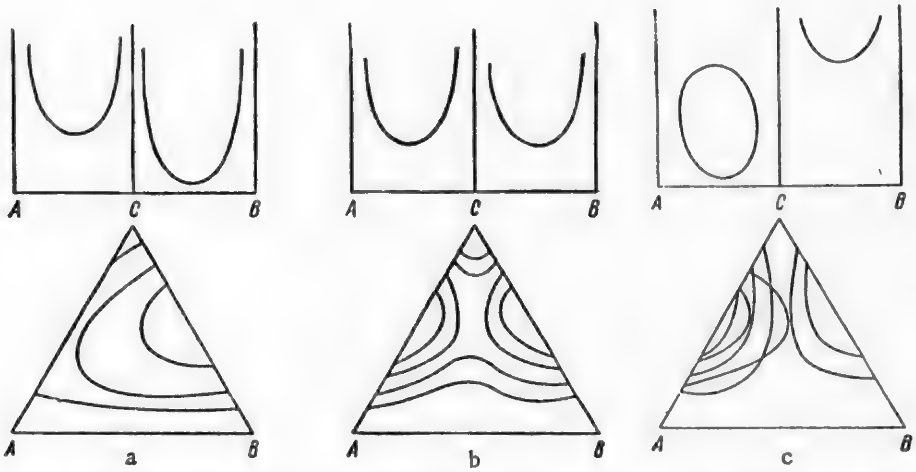


Fig. 2. Possible types of structural diagrams of ternary liquid systems having two limited systems with lower critical temperatures of solution and a third limited system with normal relationships of the components.

Type 1b. Let the lower critical points of discontinuity of solubility in the limited stratifying systems A − C and B − C correspond to one temperature or to very close temperatures. This indicates that the chemical compounds existing in the given systems are approximately equal in thermal stability. The discontinuity in solubility arises on the side boundaries in the form of two independent regions that quickly expand with a rise in temperature. The isotherms of the separate regions of stratification, moving toward each other, join in their ternary critical points and give a single region with two lines of saturated solutions. Repeating the general form of the separate isotherms, the binodal curves for temperatures above their point of union will be characterized by a mutually directed concavity. The latter should gradually disappear with a further increase in temperature. Such a type of structural diagram for a liquid ternary system is shown in Fig. 2b.

The geometric picture of the region of stratification indicated above is a necessary result of the presence of three prevailing limited systems and their competition as the temperature changes. At the temperatures of the critical points of binary stratification, and somewhat higher, the prevailing systems are those with a discontinuity in solubility. Each of them exerts a homogenizing effect on the opposed stratification. The nodes of the separate regions of stratification are directed toward these mutually homogenizing systems. With a rise in temperature, the discontinuity in solubility of the liquid phases in the systems A – C and B – C increases, and these systems lose their prevailing role, giving it over to the homogeneous system A – B. The nodes of the region of stratification begin to diverge in its direction. The continuous shift in the prevailing effect leads to different qualitative phenomena. Instead of two separate regions of stratification, a single one arises, which, however, preserves the elements of the former.

Type 1c. Let one of the limited systems, for example, A – C, have a closed region of stratification with an upper critical temperature of solution less than the lower critical temperature in the second stratifying system B – C. In this case, we should expect the existence of two independent regions of stratification. Actually, a discontinuity in solubility in the ternary system will develop from the lower critical point of the system A – C, gradually expanding as the temperature rises. This expansion will reach its maximum limit at temperatures corresponding to the greatest diameter of the conjugated solutions of the limited system A – C. Above this temperature, the conjugated phases will draw together. At the same time, the range of concentrations of the ternary solutions that fall in the region of two-phase equilibrium will decrease. The region of stratification will cease to exist at the upper critical point of the system A – C before a discontinuity in solubility appears in the limited system B – C. The system B – C will exert the prevailing effect on the region of stratification, since it is homogeneous under these temperature conditions, and its components react chemically. The nodes of the region of stratification in the whole temperature range of its existence should be directed toward the system B – C.

A second region of discontinuity of solubility of the liquid phases will begin to develop from the critical point of the system B – C at temperatures at which both the limited system A – B and the system A – C are homogeneous. It is clear that one of the two homogeneous systems will prevail for a given region of stratification. In all probability the binary system A – B will play this role. The structural diagram relating to the type discussed above is shown in Fig. 2c.

We have considered the most favorable conditions for the existence of this type of structural diagram. However, it also can occur in case the critical point of the region of stratification in the system B – C is located below the upper critical point of the system A – C, but does not go beyond the boundaries of the maximum diameter connecting the conjugated solutions of the closed region of stratification. Sometimes, even here we must expect a discontinuity in the single line of the lower ternary critical points and their closing in onto the upper critical points of the same stratifying limited systems, if two different limited systems exert a prevailing effect in the region of discontinuity of solubility of the liquid phases.

SUMMARY

The possible types of structural diagrams of ternary liquid systems containing two binary stratifications with lower critical temperatures of solution have been investigated.

It has been shown theoretically that, in the absence of chemical reaction of the components of the third homogeneous limited system, three types of structural diagrams should exist. The difference in them depends only on the relative position of the temperatures of the lower critical points of the limited systems with stratification.

LITERATURE CITED

[1] R. V. Mertslin, Izvest. Akad. Nauk SSSR, Khim. Ser. 1407 (1937).

[2] V. F. Ust'-Kachkintsev, Zhur. Obshchei Khim. 7, 2063 (1937); 9, 1749 (1939).

[3] E. F. Zhuravlev, Zhur. Fiz. Khim. 12, 639 (1938); Zhur. Obshchei Khim. 10, 1926 (1940).

[4] K. I. Mochalov, Zhur. Obshchei Khim. 8, 529 (1938).

[5] I. L. Krupatkin, Zhur. Obshchei Khim., Coll. II, 1221 (1953).

[6] R. V. Mertslin, ISFKhA* Akad. Nauk SSSR 18, 33 (1949).

* Bulletin of the Department of Physicochemical Analysis.

STRUCTURAL DIAGRAMS OF TERNARY LIQUID SYSTEMS CONTAINING TWO BINARY STRATIFICATIONS WITH LOWER CRITICAL TEMPERATURES OF SOLUTION

II. STRATIFICATION IN THE SYSTEMS TRIETHYLAMINE – PYRAMIDON – WATER AND DIANTIPYRINOMETHYL-METHYLAMINE – PYRAMIDON – WATER

E. F. Zhuravlev

Perm State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 12-20, January, 1960

Original article submitted December 22, 1958

In the first communication [1], the general theory of three-component liquid systems containing two binary stratifications with lower critical temperatures of solution was presented. We showed that the geometrical form of the structural diagrams of such ternary systems depends first of all on the physicochemical interrelationship of the components of the third limited homogeneous system. In the absence of reaction between its components, three types of structural diagrams would be expected. The difference between them depends only on the temperature position of the critical points of the limited stratifying systems.

No experimental information existed on systems with the type of relationship between the components that is under consideration, except for a single report by I. L. Krupatkin [2]. Therefore, we set ourselves the task of selecting systems for which the different structural diagrams resulting from the theory are realized. Specifically, we investigated the equilibria of the liquid phases in the systems triethylamine – pyramidon – water and diantipyrinomethyl-methylamine – pyramidon – water. The third type of structural diagram had been found in a study of the solubility of the liquid phases in the system pyramidon – diethylamine – water [2]. However, I. L. Krupatkin, starting from false premises, had presented an erroneous treatment of the observed phenomena. We considered it possible to use the experimental observations of I. L. Krupatkin in our work but to give a different physicochemical interpretation of them.

EXPERIMENTAL

In our investigation, the following materials were used: freshly distilled water; pharmacopeia grade pyramidon, kept for some time over anhydrous calcium chloride; commercial triethylamine, digested over solid alkali and distilled over the temperature range 89.2-89.6°; diantipyrinomethyl-methylamine was prepared by us (we employed the method described by S. Mannich [3], but the recrystallized product was dried at 120-125°; it melted at 150°).

The investigation of the solubility of the liquid phases in both the binary and the ternary systems was carried out by the visual polythermal method of V. F. Alekseev [4].

The system triethylamine – pyramidon – water is composed of three limited binary systems: triethylamine – water, pyramidon – water, and triethylamine – pyramidon. The first binary system has been the subject of repeated investigations [4-6]. The components of the system have an unlimited mutual solubility below 18°. Above this

temperature a discontinuity in solubility of the liquid phases occurs, with a lower critical point. The system pyramidon — water was first investigated with respect to solubility by Charonnat [7]. According to his data, the system has a closed region of stratification with a lower critical point at 70° and an upper one at 190°.

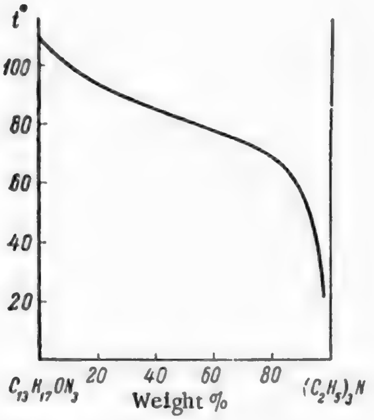


Fig. 1. Melting diagram of the system pyramidon — triethylamine.

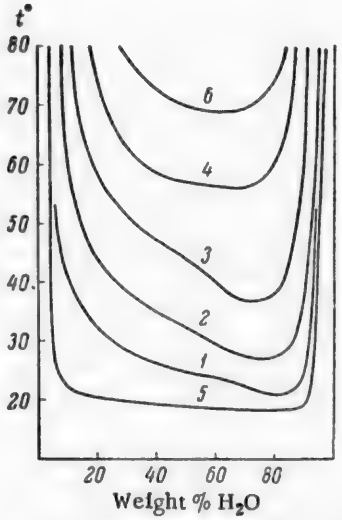


Fig. 2. Polythermal cross sections of the ternary system triethylamine — pyramidon — water. 1) 20; 2) 40; 3) 60; 4) 80 wt. % of pyramidon in binary mixtures with triethylamine; 5) polytherm of the system triethylamine — water; 6) polytherm of the system pyramidon — water.

The solubility of the solid phases of the system was investigated by S. I. Kaplan and F. E. Rabinovich [8]. The system is of the monotectic type with a strongly developed field of crystallization of pyramidon. At 73° the monotectic line dissects the region of stratification, throwing its lower portion into a region of metastable equilibrium. The components of the two systems enter into chemical reaction (otherwise, it is difficult to explain the existence in them of stratification with lower critical temperatures of solution). The liquid products of hydrated pyramidon have a greater thermal stability than those of triethylamine, as is indicated, it seems to us, by the temperature position of the lower critical points of the regions of stratification.

TABLE 1

Solubility in the System Pyramidon — Triethylamine

Pyramidon content (in wt. %)	Stratification temperature	Pyramidon content (in wt. %)	Stratification temperature
85.0	95.7°	24.2	71.8°
66.1	87.1	13.0	63.5
53.9	82.8	6.3	48.4
39.4	78.0	2.6	28.6

The third limited system, triethylamine — pyramidon, has not been described in the literature. The two substances in the system are similar in their chemical functions. We expected that they would have a nearly normal relationship. To verify our assumptions, we studied the solubility in the system pyramidon — triethylamine. The results of our observations are given in Table 1. They also are depicted in Fig. 1. As can be seen, the melting diagram of this system has a very clearly developed field of crystallization of pyramidon. Its solubility line is an S-shaped curve. This indicates not only a weakening of the reaction of the components, but also that the system probably is close to stratification.

Thus, the ternary system triethylamine – pyramidon – water that we selected is characterized by a limited contour that fully satisfies the structural diagram of type 1, the general theory for which has been given in our first communication. It remained only to subject this ternary system to experimental study.

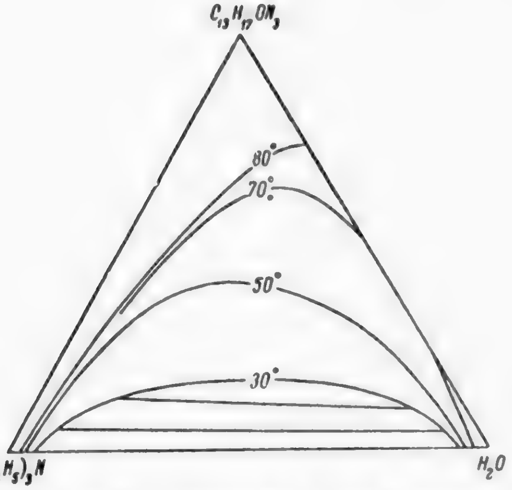


Fig. 3. Solubility isotherms and lines of conjugated solutions of the 30° isotherm of the system triethylamine – pyramidon – water.

To establish the temperature and concentration boundaries of the region of stratification in the system, we took four polythermal cross sections. They passed through the apex of the composition triangle of the system corresponding to water onto the triethylamine – pyramidon side. For each section the pyramidon content (in wt.%) in the binary mixtures with triethylamine was kept constant.

Besides the cross sections, we studied the binary systems triethylamine – water and pyramidon – water with regard to stratification. Our experimental results were in full agreement with the data of the authors who had studied these systems previously. All of the numerical data of the investigation are presented in Tables 2-4 and graphically in Fig. 2. In Fig. 3 the separate isotherms of the region of stratification of the ternary system are given. They were constructed by using the polythermal cross sections and the method of graphical interpretation.

TABLE 2

Stratification in the System Triethylamine – Water

Water content (in wt. %)	Homogenization temperature
3.4	49.5°
7.1	24.3
13.0	21.0
22.9	19.8
34.9	19.5
44.9	18.8
56.9	18.4
72.0	18.0
91.0	19.0
94.8	32.5
97.3	57.5

TABLE 3

Stratification in the System Pyramidon – Water

Water content (in wt. %)	Homogenization temperature
26.0	84.5°
28.7	80.0
32.6	75.5
39.1	72.2
49.8	69.8
60.6	70.0
69.6	71.0
77.5	72.9
82.2	76.3
85.4	82.0
86.8	86.4

The lines of the conjugated solutions were determined for the 30° isotherm.* They were found by the method of cross sections [9]. For this purpose three solutions of the binary system triethylamine – water were prepared, containing 25, 50, and 75 wt. % triethylamine. Pyramidon was added to a weighed sample of these homogeneous mixtures. The ternary mixtures made up in this way were held in a thermostat at 30° for the establishment of equilibrium between the liquid phases. Then a certain amount of the upper layer was withdrawn and its index of refraction was measured (Table 5, Fig. 4). With the aid of the graph in Fig. 4, the composition

* Determined by M. I. Leonova.

of the conjugated solutions was determined; for a given value of the index of refraction, the corresponding pyramidon content was determined from the lines I, II, and III. Transfer of the values found according to the arrangement of the cross sections to the plane of the composition triangle of the system gives three points, and drawing a straight line through them until it intersects with the binodal curve locates the conjugated phases.

TABLE 4

Stratification in the System Triethylamine – Pyramidon – Water

Water content (in wt. %)	Homogenization temperature
Section 1 (20 wt. % pyramidon in binary mixtures)	
4.5	72.6°
8.6	41.5
15.5	34.0
24.4	29.8
33.2	27.0
49.6	24.9 *
65.3	23.2
77.6	21.5
84.2	21.2
90.0	24.0
93.5	36.2
Section 2 (40 wt. % pyramidon in binary mixtures)	
7.4	76.0°
11.5	52.5
18.6	44.2
30.0	37.8
40.0	33.9
55.0	30.6
65.2	28.5
75.2	26.7
80.6	27.5
90.7	35.0°
95.5	75.1
Section 3 (60 wt. % pyramidon in binary mixtures)	
13.4	68.5°
25.0	52.5
39.9	47.4 *
55.8	41.6
66.4	38.2
72.0	37.0
78.9	37.5
87.3	46.1
90.0	70.0
Section 4 (80 wt. % pyramidon in binary mixtures)	
20.0	73.0°
29.6	62.2
42.1	57.5
54.2	57.0 *
66.0	56.5
77.8	59.0
86.0	70.4

* Critical phenomena.

The system diantipyrinomethyl-methylamine – pyramidon – water.* This system is made up of three binary systems: pyramidon – water, diantipyrinomethyl-methylamine – water, and pyramidon – diantipyrinomethyl-methylamine. The first binary system has been considered above. The system diantipyrinomethyl-methylamine – water was studied by us with respect to solubility of the liquid phases. The numerical data are given in Table 6 and the information is presented graphically in Fig. 5. The data obtained show that the system has a discontinuity in solubility of the liquid phases with a lower critical temperature of solution. The critical solution corresponds to 68° and contains 67 wt. % water. The region of stratification from the critical point to 101° is metastable. At 101° there is a monotectic phase reaction in the system. Confining ourselves to the specific problem, we did not attempt to follow the behavior of the region of stratification above 100°, and did not study the solubility of the solid phases. It is completely probable that the system has a closed region of stratification.

* Experimental study of the system was participated in by M. I. Kalmykov.

TABLE 5

Index of Refraction of Upper Layer of Heterogeneous Region of the System Triethylamine – Pyramidon – Water at 30°

Section No.	Pyramidon cont. of ternary mixt. (in wt. %)	n_D^{30}	Section No.	Pyramidon cont. of ternary mixt. (in wt. %)	n_D^{30}
I	0.0	1.3980	II	5.0	1.4053
	5.0	1.4060		10.0	1.4135
	10.0	1.4150		15.0	1.4225
	15.0	1.4246	III	5.0	1.4047
				10.0	1.4120
				15.0	1.4200

TABLE 6

Stratification in the System Diantipyrinomethyl-methylamine – Water

Water content (in wt. %)	Temp. of homogenization	Water content (in wt. %)	Temp. of homogenization
41.5	88.0°	76.4	68.2°
48.1	76.0	82.1	70.5
55.5	70.9	86.3	75.4
62.5	68.2	90.0	88.9
70.1	68.0 *		

* Critical phenomena

TABLE 7

Stratification in the System Diantipyrinomethyl-methylamine – Pyramidon – Water

Water content (in wt. %)	Temperature of homogenization	Water content (in wt. %)	Temperature of homogenization
Section 1 (25 wt. % pyramidon in binary mixtures)		Section 3 (60 wt. % pyramidon in binary mixtures)	
37.4	95.5°	34 8	88.0°
41.8	85.0	39.4	81.5
45.8	79.5	46.7	76.5
50.5	75.7	54.1	74.0
57.1	73.0	63.0	73.6 *
63.8	72.1 *	70.7	74.4
68.9	71.9 *	76.9	76.0
74.3	72.5	81.2	78.5
78.6	74.0	85.1	84.1
83.3	78.0	87.8	91.6
87.4	85.1		
Section 2 (50 wt. % pyramidon in binary mixtures)		Section 4 (80 wt. % pyramidon in binary mixtures)	
36.4	89.5°	29.3	89.0°
44.8	78.7	33.4	81.8
50.1	75.8	40.7	75.5
59.5	74.1	51.4	72.5 *
64.0	73.8 *	60.1	72.0 *
69.2	73.9	67.1	72.5
74.2	74.5	72.5	73.6
81.9	79.0	76.1	75.0
87.2	88.0	79.0	77.1
		81.7	79.8
		84.8	84.6
		87.6	92.0

* Critical phenomena..

The third limited system pyramidon – diantipyrinomethyl-methylamine had not been investigated previously. We did not study it either. We considered that this was not necessary because, like the system pyramidon – triethylamine, the relationship of these amines should be nearly normal.

The two stratifying binary systems have lower critical temperatures of solution that are almost equal. With a normal relationship of the components of a homogeneous binary system, this should lead to the second variety of structural diagram for ternary systems of type 1.

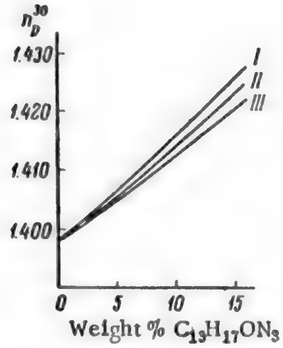


Fig. 4. Functional relationship of index of refraction of upper layer of heterogeneous region of the system triethylamine – pyramidon – water to the pyramidon content of the ternary mixtures.

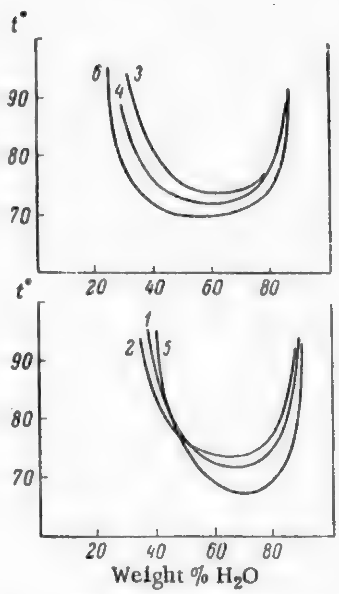


Fig. 5. Polythermal cross sections of the ternary system diantipyrinomethyl-methylamine – pyramidon – water. 1) 25; 2) 50; 3) 60; 4) 80 wt. % pyramidon in binary mixtures with diantipyrinomethyl-methylamine; 5) polytherm of the system diantipyrinomethyl-methylamine – water; 6) polytherm of the system pyramidon – water.

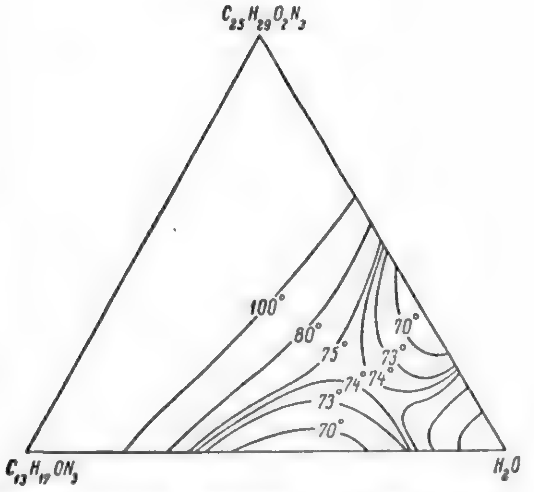


Fig. 6. Solubility isotherms of the ternary system diantipyrinomethyl-methylamine – pyramidon – water.

To establish the boundaries of the region of stratification in this ternary system, four polythermal cross sections were made. The sections passed through the apex of the composition triangle corresponding to water onto the pyramidon – diantipyrinomethyl-methylamine side with a constant pyramidon content in the binary mixtures (25, 50, 60, and 80 wt. %). The numerical data are given in Table 7 and the information is presented graphically in Fig. 5. Here the curves 1-4 correspond to the polythermal cross sections of the ternary system. Their order of enumeration is the same as for the cross sections. Curve 6 belongs to the region of stratification in the system pyramidon – water. The separate isotherms of the ternary system were constructed by the method of graphical interpolation. They are shown in Fig. 6.

DISCUSSION OF RESULTS

The investigations carried out confirm our theoretical suggestions. In the system pyramidon – triethylamine – water there exists a single region of stratification that extends from one limited stratifying system to the other. In the second ternary system, in the temperature range between the critical temperatures of solution of the liquid phases in the stratifying limited systems up to 74.5° there are two separate regions of heterogeneity. As a whole, the two-phase liquid region is separated from the homogeneous solutions by a surface which has a saddle-shaped fold. The latter appears distinctly in the isothermal cross sections of the ternary system that are shown.

The two ternary systems are characterized by the same physicochemical relationship of the components of the limited binary systems, but differ in the geometrical form of the stratification surface. This difference is a result of the number of prevailing limited systems and their gradual shift with a change in temperature. Since the general theory of this point was stated in detail in our first communication, we consider it unnecessary to discuss it again with application to these specific systems. We note, however, that our theory is fully confirmed both in the geometrical form of the polythermal and isothermal cross sections of the region of stratification and in the position of the nodes of the 30° isotherm of the system pyramidon – triethylamine – water. In the second ternary system, the lines of the conjugated solutions of the separate isotherms of the region of stratification, which are of the greatest interest to us, were not determined because of their metastability. However, this deficiency is not very substantial, since qualitative consideration of the direction of the nodes gives the same isotherms.

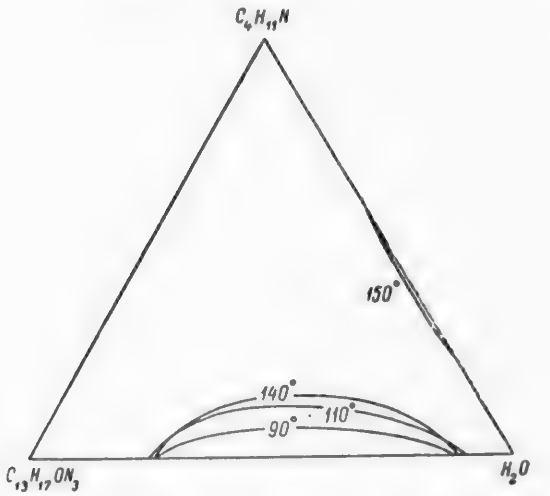


Fig. 7. Solubility isotherms of the ternary system diethylamine – pyramidon – water.

The third possible variety of structural diagram for ternary systems having the physicochemical relationship of the components of the type here under consideration was discovered by I. L. Krupatkin [2] in a study of the solubility of the liquid phases in the system pyramidon – diethylamine – water. The results of his observations are presented in Fig. 7. As can be seen from this figure, there are two independent two-phase regions in this system which do not merge under any temperature conditions. The author himself explained the observed phenomena by the chemical reaction of the components of the homogeneous predominant * system pyramidon – diethylamine. Having studied the melting behavior of the system pyramidon – diethylamine, he affirms that there exists in it a chemical compound of the composition $C_{13}H_{17}ON_3 \cdot 3C_4H_{11}N$ with an incongruent melting point of 60.5°. This compound, which is distinguished by its nature from the components that produce it, is more soluble in water. By virtue of this, the quasi-binary cross section for the system "chemical compound – water" shows a homogenizing effect on the binary stratifications of the systems pyramidon – water and diethylamine – water and results in the separate existence in the ternary system of two independent two-phase liquid regions.

We do not share the viewpoint of I. L. Krupatkin. In the system pyramidon – diethylamine, as in the system pyramidon – triethylamine, the components do not react chemically. The line of solubility of the solid phase is of the usual "atenovskogo"** type and belongs only to pyramidon over the whole concentration range of the system. Actually, if a chemical compound did exist in the system, then the mixtures of components lying between pyramidon and this compound in composition should show a temperature halt at the point of conversion of the solid phases, and should completely solidify below the peritectic. Actually, neither of these phenomena

---

* I. L. Krupatkin replaced the idea of the "prevailing system", which entered into the chemical literature in 1936, by the idea of a "predominant system." We do not fully understand this change, since the author does not reveal the advantage of this term anywhere in his work. Here let us note that I. L. Krupatkin ascribes to himself the investigation of the system pyramidon – water. We also cite other literature sources.

** Untranslatable term. Perhaps a proper noun – Atenovskii.

is observed. We consider that the system pyramidon – diethylamine has a nearly normal relationship of the components. And if this is so, then the causes leading to the observed phenomena in the ternary system are as we have stated in our first communication.

SUMMARY

1. The ternary systems pyramidon – triethylamine – water and pyramidon – diantipyrinomethyl-methylamine – water have been investigated with respect to solubility of the liquid phases. The literature data relating to the system pyramidon – diethylamine – water have been considered.

2. The geometric form of the polythermal and isothermal cross sections of the structural diagrams of the systems confirms the previously stated theoretical considerations of the possible types of structural diagrams for ternary systems made up of two binary stratifying systems with lower critical points and a third homogeneous system.

LITERATURE CITED

[1] E. F. Zhuravlev, Zhur. Obshchei Khim. 30, 7 (1960).*

[2] I. L. Krupatkin and I. A. Todorov, Zhur. Obshchei Khim. 27, 2916 (1957).*

[3] C. Mannich and B. Kather, Arch. des Pharm. 257, 1 (1919).

[4] V. F. Alekseev, Zhur. Russ. Khim. Obshchestva 8, 249 (1876); Wied. Ann. 28, 305 (1886).

[5] Rothmund, Z. Phys. Chem. 26, 433 (1898).

[6] Timmermans, Z. Phys. Chem. 58, 129 (1907).

[7] Charonnat, Compt. rend. 185, 284 (1927).

[8] S. I. Kaplan and F. E. Rabinovich, Zhur. Priklad. Khim. 21, 1162 (1948).

[9] R. V. Mertslin, Izvest. Perm. Biol. Nauch.-Issledovat. Inst. 11, 1 (1937).

* Original Russian pagination. See C. B. translation.

TERNARY MUTUAL SYSTEM OF SODIUM AND POTASSIUM ISOBUTYRATES AND NITRATES

O. I. Dmitrevskaya and N. M. Sokolov

Smolensk State Medical Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 20-25, January, 1960

Original article submitted January 7, 1959

In previous communications it has been shown that in systems of sodium and potassium isobutyrates and thiocyanates [1] and of sodium and potassium isovalerates and thiocyanates, in contrast to systems made up of the thiocyanates and the butyrates and valerates of these metals, heteroionic compounds are formed [2]. The formation of heteroionic compounds also occurs in systems of sodium and potassium acetates and salts of fatty acids with a branched carbon chain [3], but in systems of the acetates and salts of fatty acids with a normal carbon chain in the radical, a heteroionic compound is not formed [4]. The impression is created that in mutual ternary systems the presence of a salt of a fatty acid with a branched carbon chain is a sufficient condition for the formation of a heteroionic compound, independent of what sodium and potassium salts are used. To verify this conclusion, we undertook the present work.

EXPERIMENTAL

The investigation was carried out by the universally employed method of visual polythermal physicochemical analysis. Chemically pure commercial sodium and potassium compounds were recrystallized. The

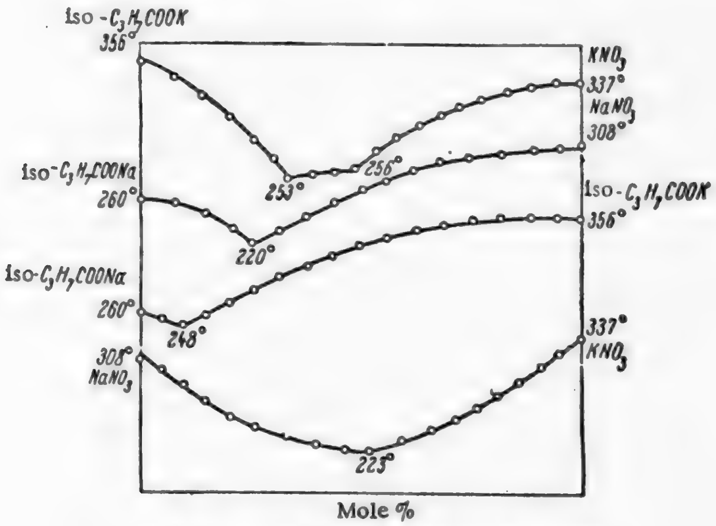


Fig. 1. Melting diagram of binary systems.

isobutyrates were synthesized by a procedure proposed by one of us [4]. The salts had the following melting points: $NaNO_3$ 308°, KNO_3 337°, iso-C_3H_7COONa 260° and iso-C_3H_7COOK 356°. In the solid state all the salts underwent isomorphic transformations: $NaNO_3$ at 270° [5, 6], KNO_3 at 124 and 316° [7, 8], iso-C_3H_7COONa at 67, 91, and 220° and iso-C_3H_7COOK at 208, 273, and 348° [9].

TABLE 1

iso-C_3H_7COOK—KNO_3		iso-C_3H_7COONa—KNO_3		iso-C_3H_7COOK—$NaNO_3$	
KNO_3 (mole %)	crystallization temp.	KNO_3 (mole %)	crystallization temp.	$NaNO_3$ (mole %)	crystallization temp.
0	356°	0	260°	0	356°
5	346	5	256	5	345
10	335	10	253	10	328
15	321	15	248	15	309
20	304	20	246	20	290
25	285	22.5	244	25	272
30	263	25	247	27.5	263
32.5	253	30	253	29	260
35	254	35	260	30	263
40	255	40	266	35	270
45	255.5	45	272	40	278
47.5	256	50	276	45	280
50	258	55	279	50	276
55	267	60	280	55	267
60	276	65	280	60	256
65	286	70	280	65	238
70	293	75	280	67.5	229
75	300	77.5	279	69	226
80	308	83.5	278	70	228
85	316	85	284	75	240
90	322	90	301	80	252
95	330	95	318	85	265
100	337	100	337	90	280
				95	294
				100	308

Binary systems (Table 1, Fig. 1). For the three binary systems comprising the marginal sides of the ternary system under consideration data are given in the literature: 1) in the structural diagram for the system $NaNO_3$—

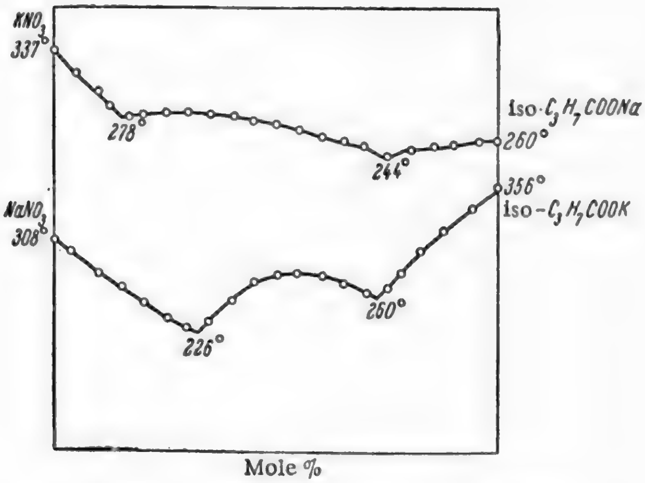


Fig. 2. Melting diagram of mixtures from diagonal cross-sections.

iso-C_3H_7COONa two branches of the melting curve intersect in a eutectic point at 220° and 25% $NaNO_3$ [10]; 2) in the diagram for the system iso-C_3H_7COONa – iso-C_3H_7COOK the two branches of the melting curve intersect in a eutectic point at 248° and 7.5% iso-C_3H_7COOK [9]; 3) the system $NaNO_3$ – KNO_3 gives a continuous series of solid solutions with a minimum m. p. of 223° at 50% KNO_3 [5]; 4) the system iso-C_3H_7COOK – KNO_3 has been investigated by us.

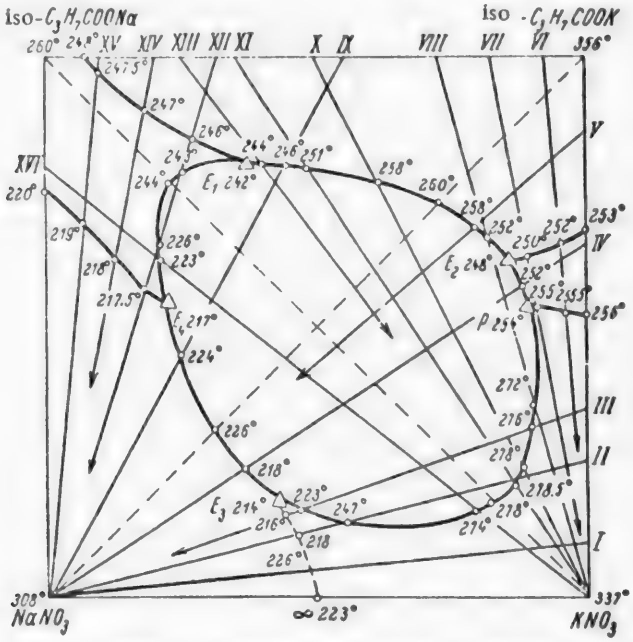


Fig. 3. Position of internal cross sections in mutual system Na, K || NO_3, iso-C_3H_7COO.

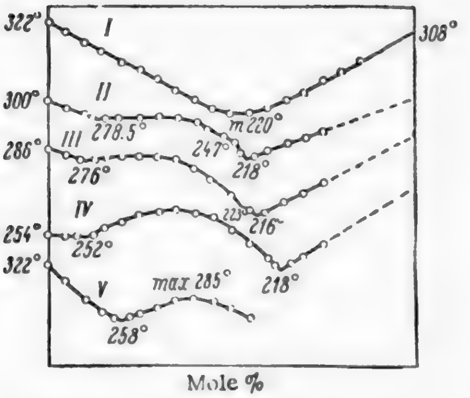


Fig. 4. Internal cross sections I-V of mutual system.

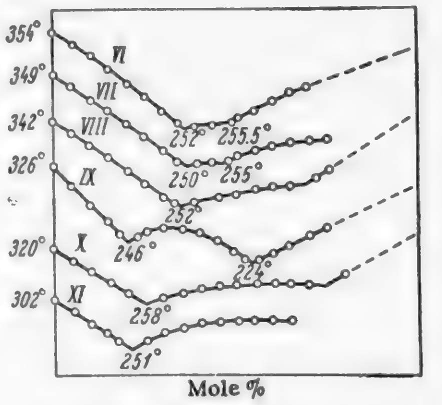


Fig. 5. Internal cross sections VI-XI of mutual system.

The three branches of the melting curve intersect in two points: in a eutectic at 253° and 32.5% KNO_3 and in a transition point at 256° and 47.5% KNO_3. The supposed composition of the compound is iso-$C_3H_7COOK \cdot KNO_3$.

Diagonal cross sections (Table 1, Fig. 2). The two diagonals of a cross section, in addition to the fields of the components, pass through the field of the heteroionic compound and therefore have three crystallization branches. In the cross section for iso-$C_3H_7COONa - KNO_3$ they intersect at 244° and 22.5% KNO_3 and at 278° and 83.5% KNO_3, and in the cross section for iso-$C_3H_7COOK - NaNO_3$ they intersect at 260° and 29% $NaNO_3$ and at 226° and 69% $NaNO_3$.

TABLE 2

Field of crystallization	Area (in %)
iso-C_3H_7COOK	21.60
iso-$C_3H_7COOK \cdot KNO_3$	1.50
KNO_3	9.10
Na, K ‖ NO_3	5.60
$NaNO_3$	18.40
iso-C_3H_7COONa	6.50
Heteroionic compound	37.30

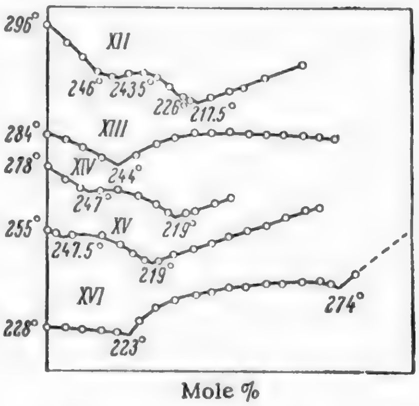


Fig. 6. Internal cross sections XII-XVI of mutual system.

In order to delimit the fields of crystallization and to find the nonvariant points, we studied 16 internal cross sections, the position of which is given in Fig. 3, and the characteristics of which are given in Figs. 4-6.

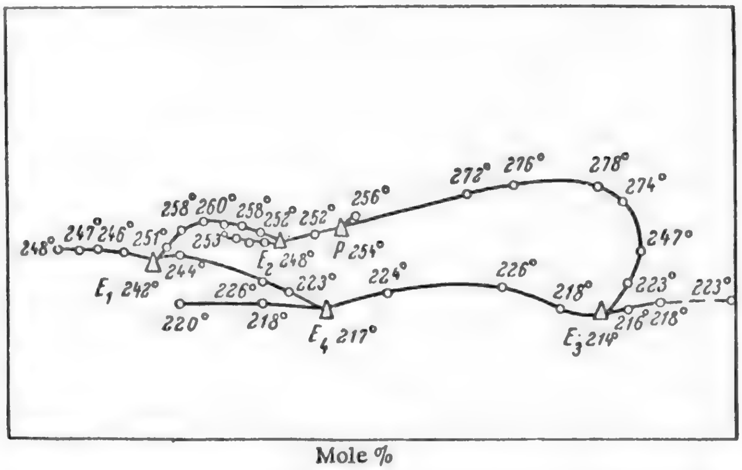


Fig. 7. Projection of lines of joint crystallization on the side iso-$C_3H_7COONa - NaNO_3$.

Melting diagram of mutual system. From the results of the investigation of the binary systems, the diagonals, and the 16 internal cross sections we constructed a projection of the curves of joint crystallization on the plane of the polytherm of the binary system sodium isobutyrate – sodium nitrate (Fig. 7), which made it possible to determine the position of the ternary and isothermal points on the curves of joint crystallization. The projections of the diagram of the liquidus of the ternary mutual system on the composition square with isotherms drawn through 20° is given in Fig. 7.

The whole surface of the liquidus of the ternary system is divided into seven fields (Table 2) because of the breakdown of the solid solutions of Na, K | NO_3, the presence of the heteroionic compound, and a compound on the side iso-$C_3H_7COOK - KNO_3$.

As can be seen from the data of Table 2, the greatest area belongs to the heteroionic compound, which provides a basis for the assumption that the formation of this compound is dominant in the reaction of the components of the system.

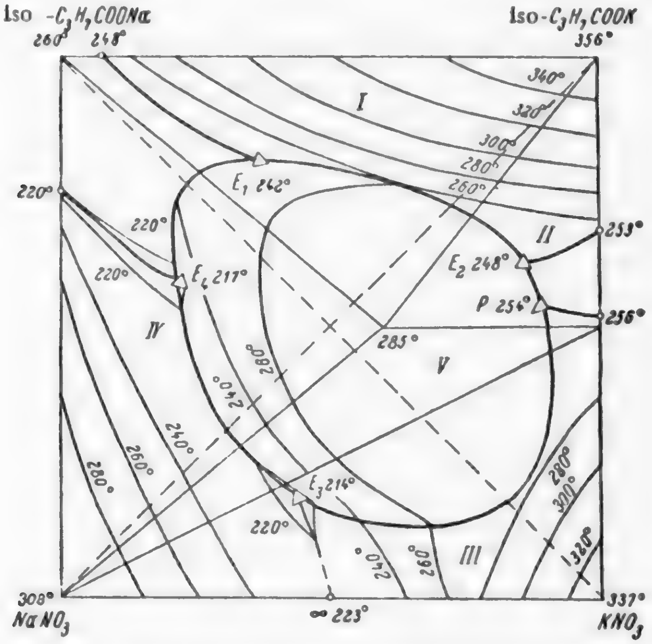


Fig. 8. Projection of surface of crystallization of mutual system Na, K || NO_3, iso-C_3H_7COO on the composition square.

The four secants starting from the pole of the heteroionic compound, for which the composition iso-$C_3H_7COOK \cdot NaNO_3$ is assumed, and the secant running down from the pole of the compound iso-$C_3H_7COOK \cdot KNO_3$ to the $NaNO_3$ corner divide the surface of the liquidus into five phase triangles, to each of which corresponds a ternary nonvariant point: I) iso-$C_3H_7COONa \cdot KNO_3$ – iso-C_3H_7COOK – iso-C_3H_7COONa with a eutectic point E_1 at 242° and 62.5% iso-C_3H_7COONa, 17.5% iso-C_3H_7COOK, and 20% KNO_3; II) iso-$C_3H_7COONa \cdot KNO_3$ – iso-C_3H_7COOK – iso-$C_3H_7COOK \cdot KNO_3$ with a eutectic point E_2 at 248° and 14.5% iso-C_3H_7COONa, 47.5% iso-C_3H_7COOK, and 38% KNO_3; III) iso-$C_3H_7COOK \cdot KNO_3$ – $NaNO_3$ – KNO_3 with a eutectic point E_3 at 214° and 18.5% iso-C_3H_7COONa, 39.5% $NaNO_3$, and 42% KNO_3; IV) iso-$C_3H_7COONa \cdot KNO_3$ – $NaNO_3$ – iso-C_3H_7COONa with a eutectic point E_4 at 217° and 20.5% KNO_3, 21% $NaNO_3$, and 58.5% iso-C_3H_7COONa; V) iso-$C_3H_7COONa \cdot KNO_3$ – $NaNO_3$ – iso-$C_3H_7COOK \cdot KNO_3$ with a transition point P at 254° and 11% iso-C_3H_7COONa, 44% iso-C_3H_7COOK, and 45% KNO_3.

SUMMARY

1. A melting diagram has been prepared for the ternary system of the isobutyrates and nitrates of sodium and potassium.

2. The formation in this system of a heteroionic compound, probably with the composition iso-$C_3H_7COONa \cdot KNO_3$, has been established.

3. The melting relationships of the binary system iso-C_3H_7COOK – KNO_3 have been investigated for the first time.

LITERATURE CITED

[1] N. M. Sokolov, Thesis Paper, Seventh Conference Smolensk State Med. Inst. (1953).

[2] N. M. Sokolov, Thesis Paper, Third All-Union Conference on Physicochemical Analysis (Moscow, 1955).

[3] N. M. Sokolov and É. I. Pochtakova, Thesis Paper, Ninth Conference Smolensk State Med. Inst. (1955).

[4] N. M. Sokolov, Zhur. Obshchei Khim. 24, 1581 (1954);* Zhur. Obshchei Khim. 27, 840 (1957).*

[5] A. G. Bergman and S. P. Berul', ISFKhA Akad. Nauk SSSR 21, 178 (1958).

[6] F. C. Krachek, J. Am. Chem. Soc. 53, 2607 (1931).

[7] Technical Encyclopedia. Handbook of Phys., Chem., and Tech. Values 6 (1931). [In Russian].

[8] V. A. Sokolov and N. E. Shmidt, ISFKhA Akad. Nauk SSSR 26, 123 (1956).

[9] N. M. Sokolov, Thesis Paper, Tenth Conference Smolensk State Med. Inst. (1956).

[10] N. M. Sokolov, Zhur. Obshchei Khim. 24, 1150 (1954).*

* Original Russian pagination. See C. B. translation.

RULE FOR POSITION OF THE NODES OF THE THREE-PHASE LIQUID CONDITION IN FOUR-COMPONENT SYSTEMS

R. V. Mertslin and N. I. Nikurashina

Saratov State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 25-29, January, 1960

Original article submitted February 26, 1958

Since this problem is being set up for the first time, there is no previous literature on the subject. Inasmuch as the equilibrium condition for three conjugate liquid phases is expressed geometrically by a triangle whose apices correspond to the equilibrium phases and the sides of which correspond to the three nodes which connect these phases by pairs, the problem under consideration led to a search for some regularity in the arrangement of the triangles for the three liquid phases, which in their conjunction form some three-phase space in the composition tetrahedron.

To start with, we shall take the most general case of a four-component system that includes a three-phase condition where the latter is formed within the space of the composition tetrahedron from one of its lateral faces to another. Such an instance is shown graphically in Fig. 1, from which we can see all of the necessary details relative to such a system. Thus, it can be seen that the space of the three liquid phases $l_1 l_2 l_3 l_1' l_2' l_3'$ passes through the whole tetrahedron from the face ACD to the face BCD, that its three sides – $l_1 l_2 l_1' l_2'$, $l_1 l_3 l_1' l_3'$, and $l_2 l_3 l_2' l_3'$ – are curved surfaces, each of which is contiguous to a space of two-phase conditions, respectively, $l_{CA} l_{AC} l_{CB} l_{BC} l_1 l_2 l_1' l_2'$, $l_{DA} l_{AD} l_{DB} l_{BD} l_1 l_3 l_1' l_3'$, and $l_{CB} l_{BC} l_2 l_3 l_2' l_3'$, and that consequently any cross section of this space passed parallel to the base will have a field bounded by two curved lines. Any vertical section of the space of three liquid phases passed through the vertex of the tetrahedron and the edge DC onto the side AB will contain a field of equilibrium of three liquid phases bounded by three curved lines. In this same case,

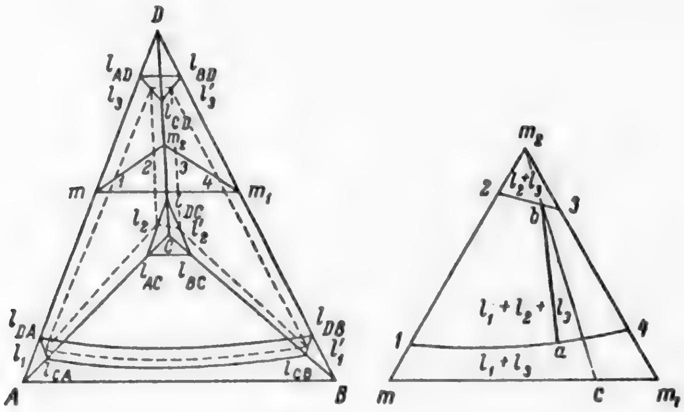


Fig. 1

when the plane of the vertical section coincides with the plane of the triangle of the conjugate phases, the field of three-phase equilibrium will be bounded by the nodes, i.e., by straight lines. It is worthy of note that of the six bounding binary systems there is only one binary homogeneous system, A – B, and all the rest show stratification. Hence, we may conclude that this binary system is predominent, i.e., that we can expect an expression of the reaction of its components in the geometric character of the curves and the surfaces of some of the heterogeneous conditions, among them the three-phase condition. Furthermore, our problem becomes completely defined. It is impossible to look for regularity in the arrangement of the nodes (of the triangles) of the three-phase liquid condition without linking it with the reaction of the components of the system. Such a problem, taking into consideration the tremendous variety of entirely unconnected separate cases of four-component systems that include three liquid phases, probably not only would not have a well-defined solution, but would lead, at best, to the establishment of separate rules having no connection with each other, i.e., to individual solutions devoid of a common physical meaning.

Put in another way, the problem leads to a search for some regularity in the arrangement within the composition tetrahedron of the triangles of three liquid phases in relation to the reaction of the components of the predominant system A – B. Simultaneously, the problem also acquires a simple physical significance. Let us actually take the system A – C – D, consisting of the three liquid phases l_1, l_2, and l_3. Let us introduce into it component B. The latter will distribute itself in some manner among all three phases. But since in the instance under investigation the reaction between components B and C, and also between components B and D is decreased, then basically the distribution will be determined by the strongest reaction, i.e., the reaction between the components A and B of the predominant system. Thus, the problem leads to a search for a rule for the distribution of one of the components of the predominant system between three liquid phases of the four-component system.

Let us proceed to the solution of the problem set up. For this purpose, let us examine a cross section of the structural diagram, the plane mm_1m_2 (Fig. 1), passed parallel to the face ABC of the composition tetrahedron. In this section there are three separate fields of heterogeneity separated from one another by the curves 23 and 14: $m_2$23, a two-phase field of the phases l_2 and l_3; the field 1234, a three-phase field of the phases l_1, l_2, and l_3; and the field 14mm_1, a two-phase field of l_1 and l_3. Curve 23 is the geometric location of the points of intersection of those nodes of the triangles of three-phase condition which form the surface $l_2l_2'l_3l_3'$, while curve 14 is formed by the points of intersection with the nodes that form the surface $l_1l_1'l_3l_3'$. The separate triangles of three-phase condition intersect as straight lines that in their aggregate form the field 1234. Therefore, on curves 23 and 14 there necessarily will be conjugate points, for example a and b, and the straight line ab joining them is the trace of the intersection of the plane mm_1m_2 of the appropriate three-phase triangle. Therefore, the rule for the arrangement of the triangles within the composition tetrahedron should be expressed as a rule for the arrangement of these straight lines on the field 1234. It is not difficult to find the latter, if the rule is known for the arrangement of the nodes of the two-phase condition for the three-component system.*

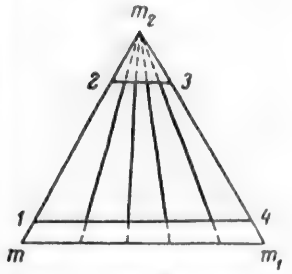


Fig. 2

Now, let us turn our attention to the fact that one and the same phase, l_3, enters into the makeup of all of the fields of heterogeneity of the cross section that was drawn and it is produced by saturation of the component D by the phases that constitute the three-component system A – B – C. On the other hand, the phases l_1 and l_2 that figure in the cross section mm_1m_2 are produced from the appropriate phases of the same three-component system by saturating them with component D. But since component D reacts weakly with components A, B, and C, separately, its presence cannot substantially change the equilibrium picture of the three-component system A – B – C. Hence, it should be concluded that curves 14 and 23 will have a geometric character determined basically by the reaction of the components of the predominant system A – B, and that the straight lines designated by their nodes, which join the corresponding points of these curves, will play the role of nodes of the two-phase field of stratification of the three-component system. Therefore, if their direction is determined in the same way as the direction of the nodes of the field of stratification, i.e., by ascertaining their deflection to the right or left

* See ISFKhA Akad. Nauk SSSR 18, 33 (1950).

from a section drawn through the vertex m_2 onto the side mm_1, for example m_2c for the nodal straight line ab (Fig. 1), then we can predict the following rules for the arrangement of the nodal straight lines, and consequently, for the triangles of three-liquid phases in the composition tetrahedron.

1. If the binary system A – B is formed by components with a normal reaction, then the nodal lines should have a nul direction (Fig. 2).

2. If the binary system A – B shows decomposition of one of its associated components, then the nodal lines should be directed to the right or left depending on the position in the composition tetrahedron of the critical node, i.e., the node formed by phases l_1 and l_2, which are in the critical state, and phase l_3. It is understood that such a node could either be within the composition tetrahedron opposite the face BCD (or ACD) or be located on this face, or could be fictitious (located on one or the other side of the tetrahedron, outside of it). In all cases, the plane passing through the points mm_1m_2 intersects such a node at a point kl_3 (Fig. 3) that is located either within the cross section, or on the straight line m_1m_2 (or mm_2), or outside of this line. If, from the point of view of an observer located in front of the side mm_1, the point kl_3 is located on the right, then the nodal lines will be directed to the left, and vice versa (Fig. 3).

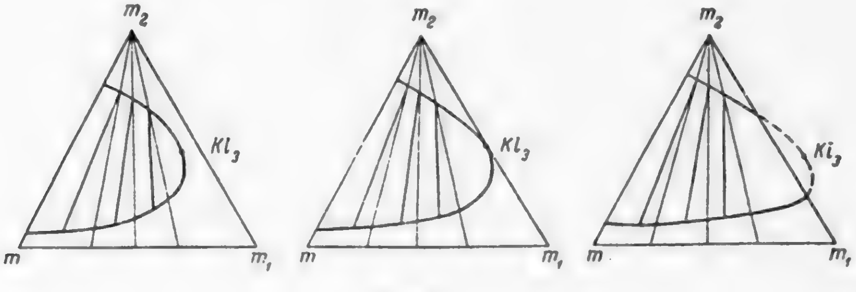


Fig. 3

3. If in the system A – B there is an undissociated compound V, then in the section mm_1m_2 the nodal line should have a nul direction with respect to the composition of this compound, and each of the curves 14 and 23 will be formed of two branches, 1S, S4 and 2S', S'3 respectively, which intersect sharply at the end points S and S' of this nodal line at an inward or outward angle (Fig. 4). Depending on the reaction between the compound V and the components A and B, and also on the location of the fictitious (in the given instance) critical nodes, the nodal lines of the fields 12SS' and SS'34 will have a right, left, or nul direction. The picture of the cross section should not change qualitatively with a change in the existing conditions.

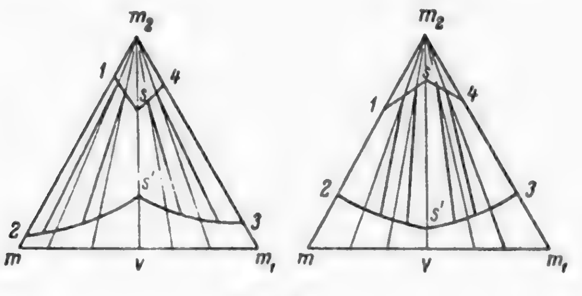


Fig. 4

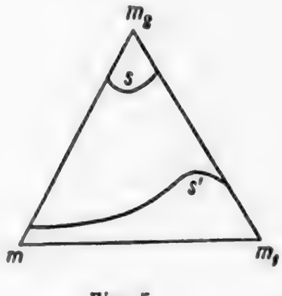


Fig. 5

4. If the compound V dissociates, then the points S and S' will be formed by the gradual intersection of the branches of the curves 14 and 23, but the position of the nodal line SS' will correspond to the composition of the compound. Finally, for the case of irrational reactions of the components we must expect on curves 14 and 23 a leveling off of the peaks S and S' and a shift of the latter on the cross section depending on the conditions existing in the system and the choice (with respect to height, i.e., to the content of component D) of the section

itself, and these extreme points, generally speaking, will belong to different triangles of three liquid phases, i.e., they will not be corresponding points. The general aspect of a cross section of such a system is shown in Fig. 5.

Thus, we come to the conclusion that the rule for the location of the nodes of the three-phase condition in the type of four-component system under consideration is directly dependent on the relationships of the components of the binary homogeneous predominant system and can be qualitatively predicted in advance, if these relationships are known. The converse also is true, i.e., on the basis of experimentally investigated cross sections of the composition tetrahedron it is possible to draw conclusions regarding the relationships of the components of the binary predominant system.

SUMMARY

1. The geometric character of cross sections drawn parallel to one of the faces of the composition tetrahedron of four-component systems that include one binary predominant system in the presence of a three-phase condition has been studied.

2. It has been suggested that the field of a three-phase condition in these cross sections will have a geometric character analogous to the field of a two-phase condition in the three-component system parallel to the face of which the cross section was drawn.

3. A representation of the nodal lines has been introduced.

4. A suggestion has been made concerning the character of the arrangement of the nodal lines on the field of a three-phase condition for the cross section under consideration in relation to the reaction of the components of the binary predominant system.

ELECTRICAL CONDUCTIVITY, VISCOSITY, AND DENSITY OF THE SYSTEMS $SnBr_4 - C_2H_5COOH$, $SnBr_4 - C_3H_7COOH$, $SnBr_4 - C_5H_{11}COOH$

T. N. Sumarokova and A. K. Nurmakova

Institute of Chemical Science of the Academy of Sciences, Kazakh SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 29-37, January, 1960

Original article submitted November 28, 1958

Stannic chloride forms complex compounds of the general formula $SnCl_4 \cdot 2RCOOH$ and $SnCl_4 \cdot 3RCOOH$ with monocarboxylic acids [1-8]. Davidson [9] described the compound $SnCl_4 \cdot 4CH_3COOH$. The behavior of stannic bromide toward monocarboxylic acids has scarcely been studied at all. It has been established that stannic bromide reacts with CH_3COOH [10] to form conducting solutions, and does not react with $CH_2BrCOOH$ [11]. Compounds of stannic bromide with glycine [12] with the compositions $SnBr_4 \cdot 4NH_2CH_2COOH$ and $SnBr_4 \cdot 2CH_3COOH \cdot 2NH_2CH_2COOH$ have been described.

The present communication gives the results of an investigation of the systems $SnBr_4 - C_2H_5COOH$, $SnBr_4 - C_3H_7COOH$, and $SnBr_4 - C_5H_{11}COOH$ by physicochemical analytical methods.

EXPERIMENTAL

Stannic bromide was synthesized and was purified by repeated distillation and fractional freezing out. The fraction boiling at 198.1° and 699 mm pressure was collected and sealed in ampoules in a special apparatus; m. p. 29° n-propionic, m-butyric, and n-caproic acids were dried over calcined copper sulfate, repeatedly distilled, fractionally frozen out, and stored in sealed ampoules. The propionic acid had b. p. 136° (692 mm), d^{20} 0.9917; butyric acid b. p. 158° (707 mm), m. p. − 4.7°, d^{20} 0.9574; caproic acid b. p. 197.7° (704 mm), m. p. − 3°, d^{20} 0.9278.

The methods of measuring viscosity, density and electrical conductivity have been described previously [13].

1. The system $SnBr_4 - C_2H_5COOH$ was studied with respect to viscosity and density at 20, 40, and 60°, and with respect to electrical conductivity at 20 and 40°. The results of the measurements are given in Tables 1 and 2. In Table 3 the results are given for the calculation of the corrected electrical conductivity, the temperature coefficient of conductivity, and the constant B calculated from the equation $\eta = Ae^{\frac{B}{RT}}$.

In Fig. 1 the composition-property diagrams are shown. From a consideration of the figure, it can be seen that the isotherm for viscosity at 20° passes through a diffuse minimum at 50 mole % and a maximum at 20 mole % $SnBr_4$. In the isotherm for viscosity at 60° the maximum and minimum are absent. The viscosity maximum occurring at 20 mole % is connected, apparently, with the formation of the compound $SnBr_4 \cdot 4C_2H_5$-COOH.

The isotherms of the specific electrical conductivity pass through a maximum at 13 mole % $SnBr_4$. With an increase in temperature the specific conductivity falls sharply, i.e., a negative temperature coefficient of electrical conductivity is observed for the system.

TABLE 1

Stannic Bromide Content		Viscosity (in centipoises)			Density (g/cm^3)		
mole %	wt. %	20°	40°	60°	20°	40°	60°
0.00	0.00	1.09	0.822	0.650	0.9917	0.9725	0.9516
5.30	24.68	1.69	1.07	0.770	1.2165	1.1861	1.1581
9.83	39.22	2.40	1.32	0.895	1.3996	1.3630	1.3286
14.70	50.50	2.74	1.44	0.961	1.5735	1.5303	1.4945
20.00	59.67	2.76	1.48	0.995	1.7456	1.6992	1.6587
23.97	65.11	2.71	1.53	1.04	1.8640	1.8160	1.7734
29.93	71.65	2.59	1.54	1.07	2.0450	1.9921	1.9485
34.98	76.09	2.48	1.54	1.10	2.1624	2.1158	2.0699
44.59	82.64	2.40	1.58	1.15	2.3937	2.3457	2.2973
59.84	89.80	2.40	1.68	1.27	2.7170	2.6667	2.6164
64.54	91.50	2.39	1.70	1.29	2.7488	2.6991	2.6493
70.25	93.32	2.48	1.78	1.35	2.8893	2.8385	2.7871
82.81	96.61	2.55	1.88	1.45	3.1174	3.0630	3.0087
88.67	97.87	2.63	1.99	1.53	3.2090	3.1555	3.0982
94.50	99.03	—	1.98	1.53	—	3.2343	3.1784
100.00	100.00	2.66 *	2.00	1.55	—	3.3091	3.2512

* Found by extrapolation of the straight line expressing the relationship of $\log \eta$ to $1/T$.

The qualitative form of the isotherms of electrical conductivity does not change when a correction is introduced for viscosity. The isotherms for the corrected conductivity pass through a maximum at 15 mole % $SnBr_4$. The negative temperature coefficient of electrical conductivity and the sharp decrease in the corrected conductivity with an increase in temperature indicate the thermal instability of the compounds formed in the system. The constant B of the equation $\eta = Ae^{\frac{B}{RT}}$, calculated for the temperature interval 20-40°, reaches a maximum value at 17-18 mole % $SnBr_4$. The isotherms of the specific volume are almost straight lines.

TABLE 2

At 20°				At 40°			
mole % $SnBr_4$	$\varkappa \cdot 10^4$ ($ohm^{-1}cm^{-1}$)	mole % $SnBr_4$	$\varkappa \cdot 10^4$ ($ohm^{-1}cm^{-1}$)	mole % $SnBr_4$	$\varkappa \cdot 10^4$ ($ohm^{-1}cm^{-1}$)	mole % $SnBr_4$	$\varkappa \cdot 10^4$ ($ohm^{-1}cm^{-1}$)
100 00	—	24.91	2.42	100.00	—	17.41	2.53
75.27	0.125	21.90	3.20	60.63	0.127	15.50	2.74
70.34	0.125	19.79	3.82	55.15	0.136	13.96	2.84
64.36	0.125	17.90	4.39	51.44	0.152	12.62	2.86
59.74	0.130	16.28	4.89	47.46	0.176	11.44	2.80
55.67	0.142	14.80	5.29	43.12	0.233	10.43	2.67
52.25	0.161	13.56	5.41	38.50	0.341	9.09	2.38
48.37	0.203	12.37	5.59	33.44	0.580	5.61	1.18
43.44	0.309	11.22	5.59	29.16	0.908	0.00	—
38.00	0.564	10.08	5.36	25.49	1.35		
32.89	1.02	8.25	4.68	22.36	1.78		
28.52	1.66	6.42	3.31	19.77	2.17		
		0.00	—				

Thus, the results of the measurements of viscosity and electrical conductivity indicate without any doubt the presence in the system of a reaction. The origin of the electrical conductivity, in our opinion, is connected with the formation of the compounds $SnBr_4 \cdot 3C_2H_5COOH$ and $SnBr_4 \cdot 4C_2H_5COOH$, which break down into their components when the temperature rises.

TABLE 3

Mole % $SnBr_4$	$\varkappa\eta \cdot 10^6$		α (in %)	$B \cdot 10^3$ (kcal)
	20°	40°	20—40°	
0	—	—	—	2.56
5	4.56	1.49	—2.61	3.58
10	12.9	3.41	—2.58	5.49
15	14.4	4.02	—2.35	5.81
20	10.7	3.27	—2.21	5.57
25	6.53	2.14	—2.11	5.14
30	3.69	1.28	—2.10	4.72
35	—	—	—1.99	4.41
40	1.11	0.47	—0.55	4.09
50	0.43	0.26	—0.56	3.54
60	—	—	—	3.21
70	—	—	—	3.02
80	—	—	—	2.80
90	—	—	—	2.63
100	—	—	—	2.60

2. The system $SnBr_4 - C_3H_7COOH$ was studied with respect to electrical conductivity, viscosity, and density at 20, 40, and 60°. The results of the measurements are given in Tables 4 and 5; in Table 6 results are given for the calculation of the corrected electrical conductivity, the temperature coefficient of conductivity, and also the constant B.

TABLE 4

$SnBr_4$ Content		Viscosity (in centipoises)			Density (g/cm³)		
wt. %	mole %	20°	40°	60°	20°	40°	60°
0.00	0.00	1.60	1.14	0.85	0.9574	0.9378	0.9188
36.51	10.35	2.55	1.51	1.05	1.3120	1.2827	1.2551
45.93	14.58	2.88	1.68	1.13	1.4445	1.4103	1.3792
55.77	20.22	3.01	1.74	1.19	1.6124	1.5748	1.5399
60.24	23.32	2.99	1.71	1.17	1.7020	1.6620	1.6263
67.20	29.10	—	—	—	1.8610	1.8192	1.7818
71.14	33.13	2.97	1.84	1.26	1.9698	1.9272	1.8858
76.91	40.10	2.93	1.86	1.29	2.1473	2.1018	2.0500
80.28	44.99	2.88	1.86	1.33	2.2660	2.2192	2.1757
84.68	52.62	2.77	1.85	1.34	2.4470	2.3991	2.3518
89.53	63.23	2.72	1.88	1.40	2.6787	2.6282	2.5795
93.19	73.33	—	1.93	1.44	2.8350	2.8316	2.7803
97.90	90.34	—	1.96	1.51	3.2044	3.1476	3.0914
100.00	100.00	2.66	2.00	1.55	—	3.3091	3.2512

The composition-property diagrams are given in Fig. 2. The isotherm for the density at 20° passes through a maximum at 25 mole % $SnBr_4$. With an increase in temperature the viscosity maximum shifts in the direction of stannic bromide and becomes flatter. At 60° the maximum disappears entirely, and the viscosity isotherm becomes a curve concave toward the composition axis. The isotherms of electrical conductivity pass through a

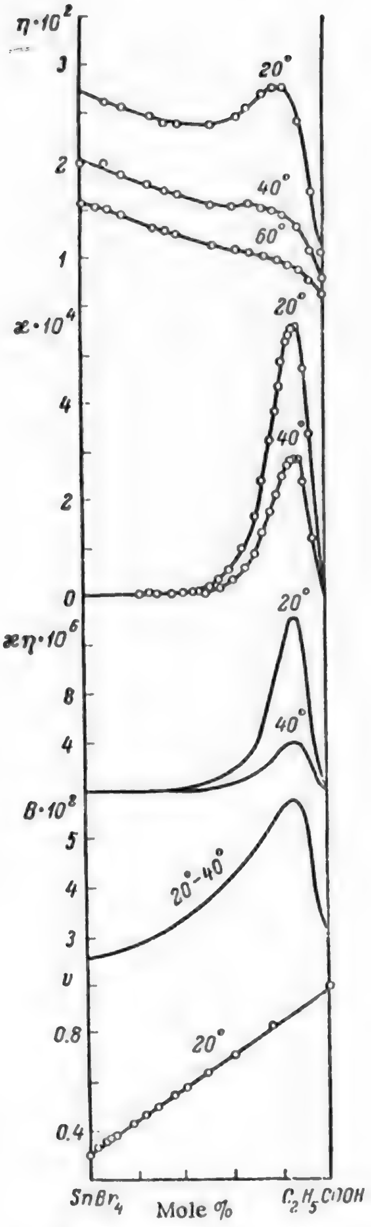


Fig. 1. Composition—property diagrams for the system $SnBr_4 - C_2H_5COOH$.

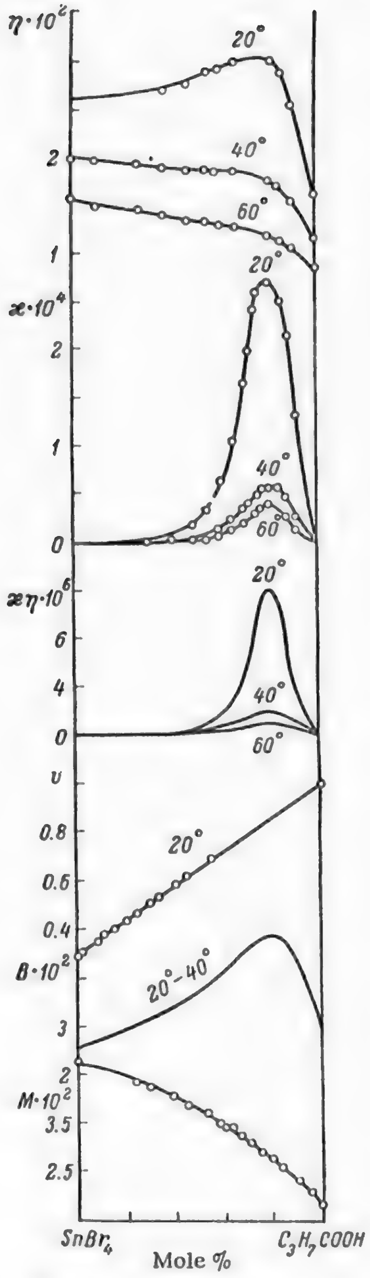


Fig. 2. Composition— property diagrams for the system $SnBr_4 - C_3H_7COOH$.

maximum at 20 mole % $SnBr_4$. The temperature coefficient of the specific electrical conductivity (Table 6) over the whole concentration range is negative. The isotherms for the corrected electrical conductivity pass through a maximum at 20 mole % $SnBr_4$, which indicates the formation of the compound $SnBr_4 \cdot 4C_3H_7COOH$. The maximum value of the corrected electrical conductivity decreases with an increase in temperature from 20 to 60° by approximately 9 times. The relationship between the constant B and the composition is expressed

in a curve that passes through a maximum at 20 mole %. Such a form for the curve apparently confirms the formation in the system of the compound $SnBr_4 \cdot 4C_3H_7COOH$.

TABLE 5

At 20°		At 40°		At 60°	
mole % $SnBr_4$	$\varkappa \cdot 10^4$ (ohm^{-1} cm^{-1})	mole % $SnBr_4$	$\varkappa \cdot 10^4$ (ohm^{-1} cm^{-1})	mole % $SnBr_4$	$\varkappa \cdot 10^4$ (ohm^{-1} cm^{-1})
0.00	—	0.00	—	0.00	—
9.76	13.2	9.00	2.65	9.94	1.67
12.76	21.0	13.15	4.69	13.07	2.73
15.40	24.9	15.22	5.36	15.10	3.31
20.56	26.7	19.89	5.60	20.08	4.17
23.94	25.7	23.06	5.18	23.06	3.64
25.88	24.0	25.08	4.69	25.06	3.27
28.33	19.7	28.08	3.94	27.93	2.70
30.56	16.5	30.50	3.31	30.01	2.12
35.92	10.5	34.82	2.41	35.00	1.39
40.93	6.36	40.65	1.11	40.26	0.82
46.37	3.31	44.19	0.75	44.98	0.54
51.78	1.79	50.25	0.37	50.15	0.26
61.25	0.46	59.73	0.08	59.51	0.12
70.25	0.18	—	—	69.98	0.03
81.87	0.11	—	—	—	—
91.30	0.03	—	—	—	—
100.00	—	100.00	—	100.00	—

TABLE 6

Mole % $SnBr_4$	$\varkappa\eta \cdot 10^6$			α (in %)	$B \cdot 10^3$ (kcal)
	20°	40°	60°	20—40°	
0	—	—	—	—	3.08
5	0.710	0.122	0.048	—2.43	3.65
10	3.37	0.479	0.168	—3.71	4.53
15	7.20	0.902	0.370	—3.90	4.99
20	7.90	0.974	0.480	—3.96	4.87
25	7.65	0.841	0.411	—4.06	4.67
30	5.10	0.619	0.274	—4.02	4.49
35	3.11	0.414	0.178	—4.11	4.33
40	2.02	0.250	0.103	—4.04	4.19
45	1.12	0.139	0.073	—4.04	4.03
50	0.560	0.074	0.040	—3.85	3.77
55	0.289	0.046	0.027	—3.81	3.60
60	0.150	0.019	0.014	—3.69	3.47
65	0.081	0.009	0.007	—4.26	3.35
70	0.041	—	—	—	3.25
80	—	—	—	—	3.03
90	—	—	—	—	2.81
100	—	—	—	—	2.60

Although, as we have seen, a reaction takes place in the system, the change in volume is subject to the rule for mixing. The results of cryoscopic measurements carried out in benzene are given in the form of a molecular weight—composition diagram (Fig. 2). The relationship of the molecular weight to the concentration is expressed by a curve that is concave toward the composition axis and whose form indicates the reaction of the components. According to our measurements, the molecular weight of butyric acid corresponds to a dimer.

3. The system $SnBr_4 - C_5H_{11}COOH$ was investigated with regard to viscosity and density at 20, 40, and 60°. The results of the measurements are given in Tables 7 and 8; in Table 9, we present the results of calculation of the corrected electrical conductivity, the temperature coefficient of conductivity, and the constant B. Composition— property diagrams are given in Fig. 3. The viscosity isotherms at all temperatures pass through a maximum, the position of which shifts in the direction of stannic bromide as the temperature rises. The specific electrical conductivity passes through a maximum at 28-25 mole % $SnBr_4$. When a correction for viscosity is made, the maximum in the electrical conductivity isotherms is preserved.

TABLE 7

Content of $SnBr_4$		Viscosity(in centipoises)			Density (g/cm^3)		
wt.%	mole %	20°	40°	60°	20°	40°	60°
0.00	0.00	3.03	1.98	1.39	0.9278	0.9102	0.8932
28.89	9.72	3.68	2.26	1.53	1.1787	1.1553	1.1337
46.93	18.99	3.83	2.32	1.57	1.4125	1.3847	1.3583
61.85	30.05	3.82	2.34	1.62	1.6892	1.6562	1.6247
71.27	39.67	3.69	2.31	1.62	1.9244	1.8869	1.8525
78.37	48.99	3.57	2.27	1.61	2.1520	2.1116	2.0724
85.31	60.69	3.36	2.23	1.62	2.4339	2.3863	2.3436
89.35	68.98	3.22	2.20	1.60	2.6338	2.5846	2.5394
93.17	78.32	3.01	2.11	1.56	2.8554	2.8031	2.7545
97.57	91.42	2.83	2.06	1.56	3.1666	3.1104	3.0586
100.00	100.00	2.66	2.00	1.55	—	3.3091	3.2512

The maximum in the corrected electrical conductivity, which occurs at 25 mole % $SnBr_4$, apparently indicates that when stannic bromide reacts with caproic acid, the compound $SnBr_4 \cdot 3C_5H_{11}COOH$ is formed.

TABLE 8

At 20°		At 40°	
mole % $SnBr_4$	$\varkappa \cdot 10^6$ (ohm^{-1} cm^{-1})	mole % $SnBr_4$	$\varkappa \cdot 10^6$ (ohm^{-1} cm^{-1})
0.00	—	0.00	—
10.00	0.09	4.36	0.06
14.59	0.96	13.19	0.12
20.14	2.58	15.23	0.12
24.89	4.30	20.25	0.24
28.67	3.71	26.36	0.31
34.86	3.21	30.00	0.18
39.88	2.50	35.12	0.15
44.03	1.70	40.49	0.12
49.46	1.16	45.86	0.09
54.98	0.69	49.99	0.06
60.20	0.31	59.64	0.05
65.59	0.24	82.80	—
70.70	0.18	80.00	
100.00	—	100.00	—

TABLE 9

Mole % $SnBr_4$	$\varkappa\eta \cdot 10^6$		α (in %)	$B \cdot 10^3$ (kcal)
	20°	40°	20—40°	
0	—	—	—	3.78
5	0.87	0.11	—4.00	4.37
10	2.09	0.23	—4.09	4.49
15	4.06	0.41	—4.14	4.54
20	9.61	0.58	—4.52	4.54
25	16.5	0.75	—4.65	4.51
30	15.3	0.47	—4.75	4.45
35	12.2	0.35	—4.79	4.35
40	9.23	0.16	—4.76	4.23
45	5.82	0.12	—4.84	4.14
50	3.89	0.11	—4.77	4.00
60	1.52	—	—4.78	3.70
70	0.48	—	—	3.37
80	0.15	—	—	3.11
90	—	—	—	2.85
100	—	—	—	2.60

The temperature coefficient of electrical conductivity, as in the preceding system, is negative and remains almost constant in the concentration range 5-65 mole % $SnBr_4$. The curve expressing the relationship of the constant B to composition passes through a maximum at 20 mole % $SnBr_4$, which indicates the formation of the compound $SnBr_4 \cdot 4C_5H_{11}COOH$. The specific volume of this system also is subject to the mixing rule. The molecular weight—composition diagram is a curve that is concave toward the composition axis. Such a form for the curve indicates the reaction of the components, but does not provide direct evidence of the composition of the compounds formed in the system.

The molecular weight for caproic acid also indicates a dimer.

DISCUSSION OF RESULTS

Thus, the physicochemical analysis of the systems $SnBr_4 - C_2H_5COOH$, $SnBr_4 - C_3H_7COOH$, and $SnBr_4 - C_5H_{11}COOH$ indicates the presence in them of an acid– base reaction. On the basis of property—composition diagrams, we suggest that the compounds $SnBr_4 \cdot 4C_2H_5COOH$, $SnBr_4 \cdot 4C_3H_7COOH$, $SnBr_4 \cdot 3C_5H_{11}COOH$, and $SnBr_4 \cdot C_5H_{11}COOH$ exist.

The complex compounds $SnBr_4 \cdot 2C_2H_5COOH$, $SnBr_4 \cdot 2C_3H_7COOH$, and $SnBr_4 \cdot 2C_5H_{11}COOH$ no doubt exist, although in the diagrams from the physicochemical analysis they are not indicated. Similar complex compounds $SnCl_4 \cdot 2CH_3COOH$ [3, 4] and $SnCl_4 \cdot 2C_6H_5COOH$ [1] have been isolated in crystalline form. The complex compounds $SnBr_4 \cdot 4C_2H_5COOH$, $SnBr_4 \cdot 4C_3H_7COOH$, $SnBr_4 \cdot 3C_5H_{11}COOH$, and $SnBr_4 \cdot C_5H_{11}COOH$ are electrolytes. The formation of these compounds also explains the appearance of electrical conductivity in the solutions upon mixing nonconducting starting materials [3, 5, 6, 14, 15]. The compounds with the composition ratios 1 : 3 and 1 : 4 are thermally unstable; when the temperature is raised, they easily break down into their components. The thermal decomposition of these compounds is indicated by the negative temperature coefficient of electrical conductivity and the sharp decrease in the corrected conductivity with a rise in temperature.

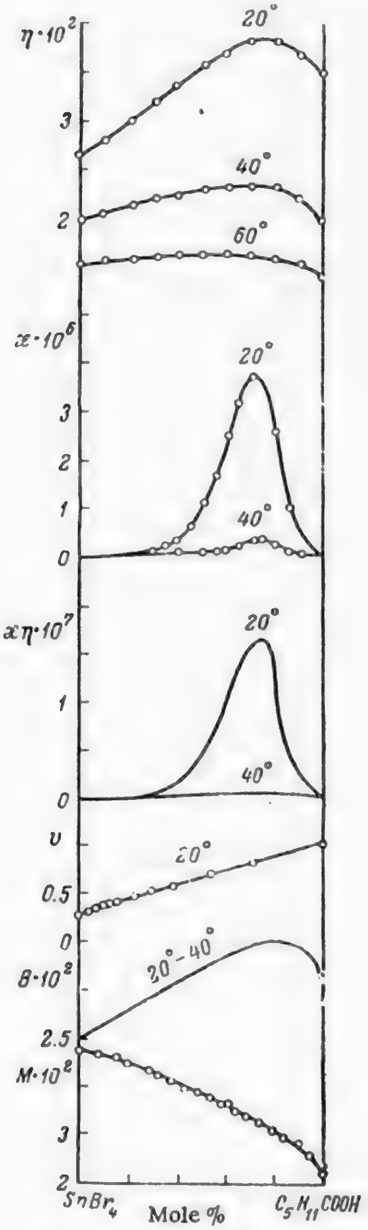


Fig. 3. Composition— property diagram for the system $SnBr_4 - C_5H_{11}COOH$.

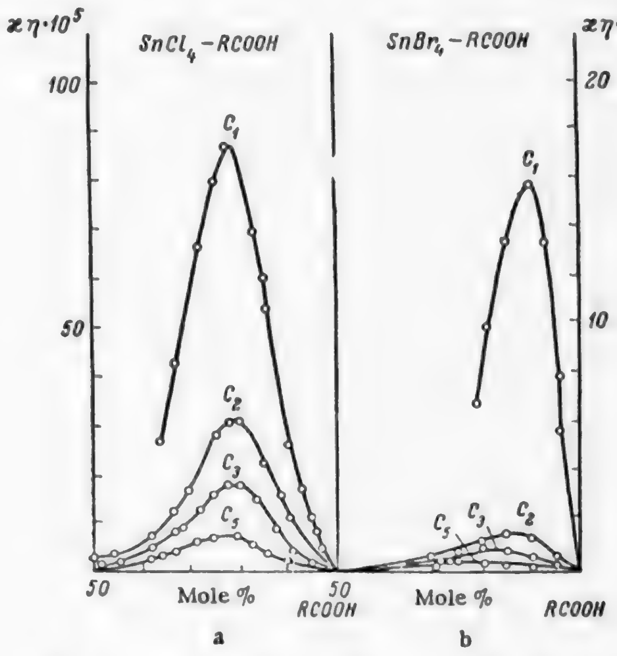


Fig. 4. Values of corrected electrical conductivity in the systems $SnCl_6 - RCOOH$ (a) and $SnBr_4 - RCOOH$ (b). C_1) CH_3COOH; C_2) C_2H_5COOH; C_3) C_3H_7COOH; C_4) $C_5H_{11}COOH$.

In Fig. 4, we compare the values for the corrected electrical conductivity of the systems $SnBr_4-CH_3COOH$ [10] (25°), $SnBr_4-C_2H_5COOH$, $SnBr_4-C_3H_7COOH$, and $SnBr_4-C_5H_{11}COOH$ at 20°. From Fig. 4 it can be seen that the values for the corrected electrical conductivity decrease in going from CH_3COOH to $C_5H_{11}COOH$. Such a decrease in the corrected conductivity shows that the extent of the acid—base reaction between stannic bromide and the carboxylic acids decreases in the direction $CH_3COOH \rightarrow C_2H_5COOH \rightarrow C_3H_7COOH \rightarrow C_5H_{11}COOH$. A similar rule is observed in the systems formed by stannic chloride [5, 6] with carboxylic acids of the aliphatic series. The value of the corrected electrical conductivity in the systems $SnCl_4-RCOOH$ characterizes the strength of the complex acids $[SnCl_4(RCOO)_2]H_2$, which decreases as the length of the radical of the carboxylic acid increases. Comparison of the values of the corrected electrical conductivity (Fig. 4, a and 4, b) shows that in the systems formed by stannic chloride this value (in spite of the higher temperature of the measurements)* is considerably greater than in the systems $SnBr_4-RCOOH$, i.e., in the systems $SnCl_4-RCOOH$ there is a more extensive acid— base reaction.

Thus, a comparison of the values of the corrected electrical conductivity graphically illustrates the complex-forming force and shows that stannic bromide is a weaker complex-forming agent than stannic chloride.

SUMMARY

1. The systems $SnBr_4-C_2H_5COOH$, $SnBr_4-C_3H_7COOH$, and $SnBr_4-C_5H_{11}COOH$ have been studied by physicochemical analysis of the liquid phase. It has been established that the components of these systems enter into an acid—base reaction. On the basis of the results of the measurements, it has been suggested that the compounds $SnBr_4 \cdot 4C_2H_5COOH$, $SnBr_4 \cdot 4C_3H_7COOH$, $SnBr_4 \cdot 3C_5H_{11}COOH$, and $SnBr_4 \cdot 4C_5H_{11}COOH$ exist.

2. It has been established that the extent of the acid—base reaction of stannic bromide with carboxylic acids decreases as the length of the radical in the acid increases.

3. On the basis of a comparison of the values of the corrected electrical conductivity of the systems $SnBr_4-RCOOH$ and $SnCl_4-RCOOH$ it has been shown that stannic bromide is a weaker aproton acid than stannic chloride.

LITERATURE CITED

[1] P. Pfeiffer, Ann. Chem. 376, 285 (1910).

[2] J. D. Stranathan and J. Strong, J. Phys. Chem. 31, 1420 (1927).

[3] M. Usanovich and E. Kalabanovskaya, Zhur. Obshchei Khim. 17, 1235 (1947).

[4] M. Usanovich and E. Kalabanovskaya, Izvest. Sektora Platiny i Drug. Blagorod. Metal. Inst. Obshchei i Neorg. Khim. Akad. Nauk SSSR 21, 230 (1948).

[5] T. Sumarokova and F. Yakovleva, Izvest. Sektora Platiny i Drug. Blagorod. Metal. Inst. Obshchei i Neorg. Khim. Akad. Nauk SSSR 25, 85 (1950).

[6] F. Yakovleva and T. Sumarokova, Izvest. Akad. Nauk Kazakh. SSR, Ser. Khim. 6, 39 (1953).

[7] F. Yakovleva and T. Sumarokova, Izvest. Akad. Nauk Kazakh. SSR, Ser. Khim. 6, 54 (1953).

[8] M. I. Usanovich and N. Shikhanova, Izvest. Sektora Platiny i Drug. Blagorod. Metal. Inst. Obshchei i Neorg. Khim. Akad. Nauk SSSR 25, 92 (1950).

[9] A. W. Davidson, Zbl. (1931), I, 3101.

[10] M. Usanovich and E. Yakovleva, Zhur. Obshchei Khim. 25, 1312 (1955).**

[11] T. Sumarokova and N. Khakhlova, Zhur. Obshchei Khim. 26, 2690 (1956).**

* Corrected electrical conductivity decreases with a rise in temperature.

** Original Russian pagination. See C. B. translation.

[12] T. Sumarokova and É. Yarmukhamedova, Zhur. Obshchei Khim. 26, 3295 (1956).*

[13] T. Sumarokova and I. Litvyak, Izvest. Sektora Platiny i Drug. Blagorod. Metal. Inst. Obshchei Neorg. Khim. Akad. Nauk SSSR 27, 127 (1952).

[14] M. Usanovich, V. Klimov, and T. Sumarokova, Doklady Akad. Nauk SSSR 113, 364 (1957).*

[15] V. Klimov, M. Usanovich, and T. Sumarokova, Izvest. Akad. Nauk Kazakh. SSR, Ser. Khim. 2/12, 3 (1957).

* Original Russian pagination. See C. B. translation.

POLAROGRAPHIC INVESTIGATION OF AMINOACETOPHENONES

II. N,N-DIMETHYL- AND N-ACETYLAMINOACETOPHENONES

V. D. Bezuglyi, V. N. Dmitrieva, and V. V. Dorofeev

Central Laboratory of the Khar'kov Dental Materials Plant and

Kharkov Polytechnic Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 38-46, January, 1960

Original article submitted May 12, 1958

In a previous communication [1] we presented the results of a polarographic investigation of o-, m-, and p-aminoacetophenones and showed the effect of the position of the amino group on the polarographic activity of these compounds.

In order to further investigate the connection between the principal polarographic characteristics and the presence in the molecule of various groups, and also the condition of the material in solution in relation to various conditions, we have also investigated the isomers of the N,N-dimethylaminoacetophenones and the N-acetoamidoacetophenones.

The results of these investigations are given in the present communication.

EXPERIMENTAL

The dimethyl and acetyl derivatives of the aminoacetophenones were synthesized by the following methods.

N,N-Dimethyl-o-aminoacetophenone was prepared by methylating o-aminoacetophenone with methyl iodide [2] and was purified by steam distillation and vacuum distillation.

N,N-Dimethyl-m-aminoacetophenone was prepared by refluxing m-aminoacetophenone with methyl iodide and sodium carbonate solution [3]. Unlike method [3], the isolation and purification of the N,N-dimethyl-m-aminoacetophenone was carried out not by vacuum distillation and pressing out the crystals that were formed in a viscous oil, which is very difficult for small amounts, but by chemical means by passing hydrogen chloride into an ether solution, the hydrochloride of the N,N-dimethyl-m-aminoacetophenone was precipitated, the precipitate was washed with ether, then dissolved in water and boiled with animal charcoal. After filtration, the amine was isolated with sodium hydroxide and steam distilled. The crystals that formed in the aqueous distillate were filtered off and the filtrate was extracted with ether. The N,N-dimethyl-m-aminoacetophenone that was recrystallized from a mixture of ethyl and petroleum ethers formed colorless needles with m. p. 41°, which agrees with the data in the literature.

N,N-Dimethyl-p-aminoacetophenone was synthesized by the method described for the meta isomer [3]. Isolation and purification was carried out in this instance by steam distillation and fractional recrystallization from petroleum ether [4]. M. p. 106°, which agrees with the data in the literature.

N-Aceto-o-amidoacetophenone was prepared by reacting o-aminoacetophenone with acetic anhydride [5, 6]. After purification by recrystallization from water, the product formed colorless needles with m. p. 77°, which agrees with the data in the literature.

N-Aceto-m-amidoacetophenone was prepared by reacting m-aminoacetophenone dissolved in acetic acid with acetic anhydride [3] and was purified by recrystallization from water or dilute alcohol. Colorless needles with m. p. 129°, which agrees with the data in the literature.

N-Aceto-p-amidoacetophenone was prepared by reaction of p-aminoacetophenone with acetic anhydride by the method used for the preparation of the ortho isomer [6]. After recrystallization from water, the compound formed colorless needles with m. p. 166°, which agrees with the data in the literature.

The method of investigation (apparatus, characteristics of the dropping electrode, and composition of the solutions) has been described previously [1].

Results of the polarographic investigation of all the isomers of the N,N-dimethyl and N-acetyl derivatives of the aminoacetophenones (half-wave potentials against a saturated aqueous calomel electrode and constants of the diffusion current) are presented in Tables 1-3 and in the polarograms (Figs. 1-6).

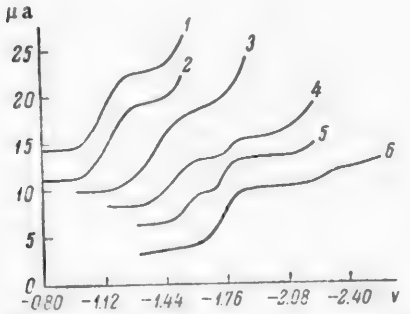


Fig. 1. Polarographic waves of N,N-dimethyl-o-aminoacetophenone on a background of buffered solutions with various pH values: 1) 2.2; 2) 3.75; 3) 6.13; 4) 7.26; 5) 10.29; 6) 11.54; concentration of depolarizer 1.55 millimoles/liter.

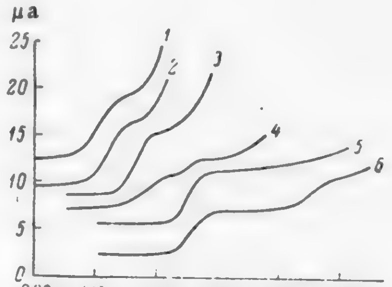


Fig. 2. Polarographic waves of N,N-dimethyl-m-aminoacetophenone on a background of buffer solutions with various pH values: 1) 2.2; 2) 3.75; 3) 6.13; 4) 7.23; 5) 10.29; 6) 11.54; concentration of depolarizer 1.145 millimoles/liter.

N,N-Dimethyl-o-aminoacetophenone on a background of acid buffer solutions produced a polarographic wave with varying values of $E_{1/2}$ from − 1.11 (pH 2.2) to − 1.37 v (pH 6.13). At pH 6.13 the polarographic wave was elongated, perhaps as a result of the superposition of two closely located waves. In solutions with pH 7.26 and above, two waves were observed, the half-wave potentials of which were − 1.48 v for the first wave and − 1.80 v for the second.

These values were almost unchanged upon further increase of the pH to 10.29. At still higher pH values (11.54) the first wave disappeared completely, but along with the second wave a third one appeared, which was poorly defined with a greatly extended rise starting at − 2.18 v.

On the background of $N(CH_3)_4I$ only one wave was observed, with $E_{1/2}$ − 1.73 v.

N,N-Dimethyl-m-aminoacetophenone in acid buffered solutions produced one wave up to pH 6.13, the $E_{1/2}$ of which changed with a change in pH from − 1.11 (pH 2.2) to − 1.33 v (pH 6.13), and then at pH 7.32 this wave decreased in height and a second wave appeared with $E_{1/2}$ − 1.61 v. At pH 10.29 and 11.54, the first wave was absent. $E_{1/2}$ for the second wave at these pH values was − 1.65 v (close to the half-wave potential of unsubstituted acetophenone). At pH 11.54, along with the diminishing second wave there appeared a third wave, starting at − 2.14 v, greatly extended and poorly defined. On the background of $N(CH_3)_4I$ one wave was observed with $E_{1/2}$ − 1.56 v.

The polarographic waves for m-dimethylaminoacetophenone at various pH values are shown in Fig. 2.

N,N-Dimethyl-p-aminoacetophenone was reduced at the dropping mercury cathode in acid medium with somewhat more difficulty than the first two compounds: up to pH 6.13 one wave was observed with $E_{1/2}$ − 1.17 v (pH 2.2) and $E_{1/2}$ − 1.42 v (pH 6.13); in this connection it should be noted that the difference in the half-wave potentials for the para isomer and the other two isomers decreased when the pH was lowered and $E_{1/2}$ for all the isomers approached $E_{1/2}$ for unsubstituted acetophenone as the pH diminished.

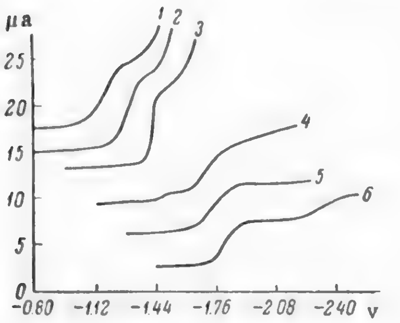


Fig. 3. Polarographic waves of N,N-dimethyl-p-aminoacetophenone on a background of buffer solutions with various pH values: 1) 2.2; 2) 3.75; 3) 6.13; 4) 7.26; 5) 10.29; 6) 11.54; concentration of depolarizer 1.145 millimoles/liter.

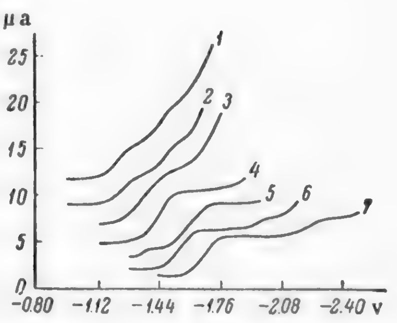


Fig. 4. Polarographic waves of N-aceto-o-amidoacetophenone on a background of buffer solutions with various pH values: 1) 2.2; 2) 3.17; 3) 3.75; 4) 6.13; 5) 7.26; 6) 10.29; 7) 11.54; concentration of depolarizer 1.14 millimoles/liter.

TABLE 1

Values of Half-Wave Potentials of the Ortho-, Meta-, and Para-Isomers of the N,N-Dimethyl- and N-Acetylaminoacetophenones in Buffer Solutions with Various pH Values

Isomer		Value of $E_{1/2}^{*}$ at pH:							
		2.2	3.17	3.75	1.63	7.26	7.32	10.29	11.54
Dimethylamino-acetophenone	o	1.11		1.15	1.37	1.48, 1.80		1.50, 1.78	1.73, 2.30
	m	1.11		1.17	1.33		1.38, 1.61	1.62	1.65, 2.27
	p	1.17		1.29	1.42	1.48		1.76	1.81, 2.32
Acetamidoaceto-phenone	o	1.23, 1.26, 1.44, 1.46		1.36	1.45	1.36, 1.57		1.55, 1.35	1.57, 1.97
	m	1.13	1.16, 1.37	1.23, 1.39	1.47	1.52	1.42, 1.58	1.54	1.60, 2.05
	p	1.20	1.22, 1.43	1.25, 1.43	1.33, 1.53	—	1.43, 1.61	1.63	1.69, 2.27

* All values of $E_{1/2}$ given with minus sign.

In solutions with pH > 6 two waves appeared instead of one – the second with $E_{1/2}$ − 1.70 to − 1.72 v; at pH 10.29 the first wave entirely disappeared and at pH 11.54 along with the diminishing second wave ($E_{1/2}$ − 1.81 v) the appearance of a third wave was observed starting at $E_{1/2}$ − 2.2 v.

N-Aceto-o-amidoacetophenone even in acid solutions (pH 2.2 and above) produced in its polarogram two distinctly defined waves. The half-wave potential of the first wave ($E_{1/2}$ − 1.23 v at 2.2) shifted in the negative direction with an increase in the pH, but the half-wave potential of the second wave remained relatively constant (− 1.44 to − 1.46 v).

This resulted in the two waves running together at pH 3.75, and one wave being formed with a height almost equal to the sum of the heights of the two waves that appeared at lower pH values.* At pH 6.13, the first wave became imperceptible, since its height fell to practically zero.

In alkaline solutions, two waves were observed, the second one starting at $E_{1/2}$ about − 1.92 and having a sloping character. The first wave had $E_{1/2}$ − 1.55 v (pH 10.29).

On the background of unbuffered 0.05 N $N(CH_3)_4I$ solution two waves were observed; the first had $E_{1/2}$ − 1.57 v and the second − 2.05 v.

N-Aceto-m-amidoacetophenone in the acid region, like the ortho isomer, gave two waves. However, in the polarogram obtained in a buffered solution with pH 2.2 only one wave was seen, the second apparently coinciding with the reduction background (hydrogen ion). At pH 3.17 and above,both of the waves mentioned were observed and the half-wave potentials became more negative as the pH increased, $E_{1/2}$ for the first wave increasing more with the rise in pH, and at a background pH of 6.13 the two waves practically ran together into one, so that beyond that point there was one wave with a constant $E_{1/2}$. At a background pH of 11.54, still another wave appeared with $E_{1/2}$ − 2.05 v.

The sum of the heights of the two waves in acid medium was approximately equal to the height of the wave at pH 6.13 and above.

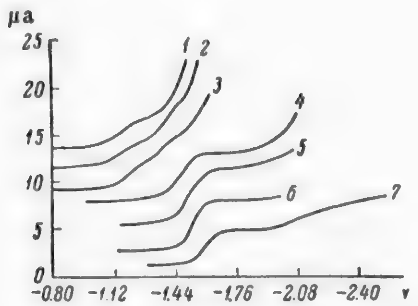


Fig. 5. Polarographic waves of N-aceto-m-amidoacetophenone on the background of buffered solutions with various pH values: 1) 2.2; 2) 3.17; 3) 3.75; 4) 6.13; 5) 7.32; 6) 10.29; 7) 11.54; concentration of depolarizer 1.11 millimoles/liter

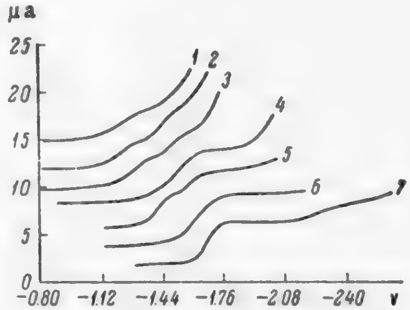


Fig. 6. Polarographic waves of N-aceto-p-amidoacetophenone on the background of buffered solutions with various pH values: 1) 2.2; 2) 3.17; 3) 3.75; 4) 6.13; 5) 7.32; 6) 10.29; 7) 11.54; concentration of depolarizer 1.11 millimoles/liter.

N-Aceto-p-amidoacetophenone produced two waves in the acid range; $E_{1/2}$ for the first wave increased approximately by 60 mv per pH unit in the direction of negative values of the potentials as the pH increased;

* In Fig. 4 (curves 1 and 2) the residual current of the background entered into the total magnitude of the current, in connection with which the total height of the waves at these pH's was somewhat greater than the actual sum of the heights of the two waves of N-aceto-o-amidoacetophenone.

$E_{1/2}$ for the second wave changed considerably less with pH ($\approx$ 30 mv per pH unit); $E_{1/2}$ for the second wave at pH 2.2 was determined with great difficulty because of the proximity of the reduction of the hydrogen ion, and we therefore did not make this determination. At pH about 7 these two waves almost ran together into one, since the half-wave potentials became very close and the bend between the two waves became difficult to distinguish. In the alkaline region at pH 10.29 one wave was observed with $E_{1/2}$ close to the value of $E_{1/2}$ for the second wave at pH about 7.

TABLE 2

Relation of Constants of Diffusion Current $\frac{I_d}{cm^{2/3}\tau^{1/6}}$ of Substituted Aminoacetophenones to pH

Aminoaceto-phenone		pH	c (mmoles/liter)	$\frac{I_{d_1}}{cm^{2/3}\tau^{1/6}}$	$\frac{I_d}{cm^{2/3}\tau^{1/6}}$	n
m	Dimethyl	2.2	1.145		3.88	2.33
p	Dimethyl	2.2	1.145		3.88	2.33
o	Dimethyl	2.2	1.55		4.01	2.42
m	Acetyl	2.2	1.11	2.06		
p	Acetyl	2.2	1.11	2.06		
o	Acetyl	2.2	1.13		3.52	2.15
m	Dimethyl	3.75	1.145		4.31	2.59
p	Dimethyl	3.75	1.145		4.63	2.78
o	Dimethyl	3.75	1.550		3.88	2.33
m	Acetyl	3.75	1.11		3.58	2.19
p	Acetyl	3.75	1.11		3.68	2.25
o	Acetyl	3.75	1.13		3.63	2.22
m	Dimethyl	7.26	1.145		3.34	2.01
p	Dimethyl	7.26	1.145		3.16	1.90
o	Dimethyl	7.26	1.55	2.23	3.34	2.01
m	Acetyl	7.26	1.11		3.26	2.00
p	Acetyl	7.26	1.11		3.04	1.86
o	Acetyl	7.26	1.13		3.20	1.96
m	Dimethyl	10.29	0.594		3.85	
m	Dimethyl	10.29	1.145		3.79	2.29
p	Dimethyl	10.29	0.594		3.66	2.18
p	Dimethyl	10.29	1.145		3.58	
o	Dimethyl	10.29	0.806	1.65	3.44	2.06
o	Dimethyl	10.29	1.55	1.47	3.42	
m	Acetyl	10.29	0.589	1.54	3.48	
m	Acetyl	10.29	1.11		3.37	2.10
p	Acetyl	10.29	0.589		3.48	
p	Acetyl	10.29	1.11		3.37	2.10
o	Acetyl	10.29	0.590		3.68	
o	Acetyl	10.29	1.13		3.57	2.22
m	Dimethyl	11.54	1.145	2.62	5.05	3.03
p	Dimethyl	11.54	1.145	3.05	4.31	2.59
o	Dimethyl	11.54	1.550	3.04	3.88	2.33
m	Acetyl	11.54	1.11	2.39	3.30	2.02
p	Acetyl	11.54	1.11	2.60	3.63	2.22
o	Acetyl	11.54	1.13	1.88	3.25	1.99

At a background pH of 11.54 the appearance of still another poorly defined wave was observed, starting at $E_{1/2}$ − 2.08 v. For the para isomer on a background of 0.05 N $N(CH_3)_4I$ two waves were observed lying very close together, the first wave having a lesser height than the second and being very poorly defined: $E^1_{1/2} = -1.48$ v; $E^2_{1/2} = -1.61$ v.

The magnitudes of the half-wave potentials of the individual isomers at various pH values are given in Table 1 and the constants of the diffusion current calculated for both the first and for the total wave are given in Tables 2 and 3.

TABLE 3

Constants of Diffusion Current of Various Substituted Aminoacetophenones on the Background of 0.05 N $(CH_3)_4NI$

Depolarizer	c (mmoles/liter)	$\frac{I_{d_1}}{cm^{2/3}t^{1/6}}$	$\frac{I_d}{cm^{2/3}t^{1/6}}$	n
Dimethylamino-acetophenone				
m	0.302		3.57	2.18
	0.592		3.66	
	0.892		3.66	
		Average	3.63	2.18
p	0.594		3.64	
o	0.411		3.78	
	0.808		3.88	
	1.189		3.56	
	1.555		3.72	
		Average	3.73	2.24
Acetamidoaceto-phenone				
m	0.294		3.39	
	0.577		3.24	
	0.850		3.19	
	1.110		3.14	
		Average	3.24	1.98
p	0.294		3.39	
	0.577		3.24	
	0.850		3.26	
	1.110		3.14	
		Average	3.28	2.01
o	0.302	2.39	3.80	
	0.592	2.34	3.76	
	0.872	2.34		
	1.140	2.33	3.65	
	Average	2.35	2.72	2.27

DISCUSSION OF RESULTS

As can be seen from the results presented in the experimental section, all of the compounds investigated were reduced at the dropping mercury electrode; however, in connection with the specific influence of both the nature of the substituent and its position in the benzene ring of aminoacetophenone the character of the polarograms of the isomers studied differed.

Thus, the para isomer of dimethylaminoacetophenone in the acid region behaved differently from the other two isomers – it was reduced in the pH range from 3 to 6.7 with somewhat more difficulty than the ortho and meta isomers, while in the case of the unsubstituted aminoacetophenones the behavior of the ortho and para isomers in this pH region was similar [1].

Thus, in the pH region where salt formation does not go to completion, i.e., the noncovalent pair of electrons on the nitrogen are not bound, the conjugation of the carboxyl group with the electron-repelling group $-N(CH_3)_2$ in the para position hinders its reduction as a result of the increase in electron density on the $>C=O$ group.

In the ortho position the effect of conjugation apparently is somewhat upset because of the steric hindrances – the escape from coplanarity of the functional group $N(CH_3)_2$ because of its larger size than the NH_2 group and the closeness of the position to the $C\begin{smallmatrix} \diagup\!\!\diagup O \\ \diagdown CH_3 \end{smallmatrix}$ group. This leads to some disturbance of the effect of the conjugation of the unshared electron pair with the π-electrons of the benzene ring and the effect of the $N(CH_3)_2$ group in the ortho position becomes similar to its effect in the meta position.

When the pH was decreased to 2.2 and below, the reduction potentials for all three isomers approached each other because of the participation in salt formation of the noncovalent electron pair on the nitrogen and the elimination of its mobility.

At the same time there was a clearly noticeable decrease in the effect of the hydrogen bond between the amino group and the carbonyl group in the case of N,N-dimethyl-o-aminoacetophenone; its reduction potential in acid medium did not become more negative than for the meta isomer, while in the case of the aminoacetophenones the presence of the hydrogen bond in the ortho isomer hinders reduction of the carbonyl group (the reduction potential of o-aminoacetophenone was determined by us at pH 1.6 and was equal to – 1.04 v, but the meta isomer under the same conditions had a reduction potential of – 0.96 v).

The above indicated spatial characteristics of the structure of N,N-dimethyl-o-aminoacetophenone (some disturbance of the coplanarity) resulted in the behavior of this isomer in the alkaline region being different from that of the para isomer – it was reduced somewhat more easily than the para isomer, but with somewhat more difficulty than the meta isomer because of the partial escape of the $-N(CH_3)_2$ group from conjugation; however, some electron donor effect of the $-N(CH_3)_2$ group was still observed: a higher negative electrode potential was required for the transfer of the second electron, as also was true for the reduction of N,N-dimethyl-p-aminoacetophenone.

As can be seen from the data of Tables 2 and 3, all of the N-substituted aminoacetophenones investigated by us were reduced with a total expenditure of 2 electrons per molecule; where two waves were observed, each of them corresponded to a one-electron process.

The $-NHCOCH_3$ group had a special effect on the character of the polarographic reduction of the carbonyl group.

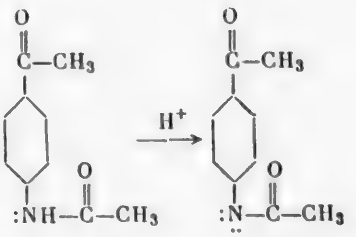
Since the tendency to salt formation was weak for all the isomers of the N-acetamidoacetophenones, even in acid medium a large difference was observed in the reduction of these isomers in comparison with the amino- and N,N-dimethylaminoacetophenones; their reduction potentials, particularly those of the ortho and para isomers, not only did not approach $E_{1/2}$ for the unsubstituted acetophenone, but even declined with a decrease in pH. All of them, upon reduction in acid medium, produced two one-electron waves, both the first and the second of these waves for the meta isomer lying at more positive potentials, while for the para and ortho isomers they were more negative. For the meta isomer, the $E_{1/2}$ of the first wave practically coincided with $E_{1/2}$ for the unsubstituted acetophenone.*

* $E_{1/2}$ for acetophenone in 0.1 N HCl is – 1.13 v.

The difficulty in reducing the carbonyl group in the N-acetamidoacetophenones in acid medium in comparison with the other derivatives considered by us is connected with their lower tendency to salt formation; thus, the electron donor effect of the $-NHCOCH_3$ group is preserved in acid medium. It should be kept in mind that the electron donor effect of the $-NHCOCH_3$ group is generally somewhat lower than that of the NH_2 group [or $N(CH_3)_2$]; however, it does occur, as can be seen from the results presented. The absence of the possibility of the transmission of this effect when the $-NHCOCH_3$ group is in the meta position in relation to the carbonyl group leads to the meta isomer being reduced (even in acid medium) in a manner similar to acetophenone.

In alkaline medium the N-aceto-o- and N-aceto-m-amidoacetophenones were reduced almost at the same potentials, but the para isomer was reduced with somewhat more difficulty. We explain this, as in the case of the dimethyl substituted derivatives, by the escape from coplanarity of the $-NHCOCH_3$ group in the ortho isomer, which leads to a lowering of the effect of the conjugation of the electronegative group $-NHCOCH_3$, while this effect remains in the para isomer. However, even in the para isomer the electronegative effect of the $-NHCOCH_3$ group is so small (especially at average pH values) that there was scarcely any great difference observed among the three isomers. This is connected with the opposing effect of the carbonyl group of the acetyl radical; therefore N-aceto-p-amidoacetophenone, for example, is reduced more easily in the alkaline region (at pH 10) than the para-amino- or para-dimethylamino isomers.

In the strongly alkaline region, in p-acetamidoacetophenone a proton apparently splits off from the amino group, which is under the acidifying influence of the acetyl group that is directly linked to it, and the free ionic charge communicates an additional electron density to the nitrogen of the amino group. This elicits a more intense shift in the electron density through the system of π-bonds of the benzene ring to the CO-group, which results in more difficult reduction of p-acetamidoacetophenone in alkaline medium than of the ortho and meta isomers and brings the magnitude of the electron-repelling effect of the acetamido group close to that of the $N(CH_3)_2$ and NH_2 groups.



The production of an extended wave in strongly alkaline media is still not clear. However, it can be assumed that it is connected with a change in the nature of the reaction at the electrode and the formation of other end products.

SUMMARY

1. The polarographic behavior of the three isomers of N,N-dimethyl- and N-acetylaminoacetophenones at the dropping mercury cathode has been investigated and their main polarographic characteristics have been determined in both buffered and unbuffered solutions.

2. A connection has been established between the effect of the nature of the substituents on the amino group of the aminoacetophenones and their position and the principal polarographic characteristics. This connection has been explained from the point of view of the electron theory of the structure of organic molecules and their state in the polarographed solution.

LITERATURE CITED

[1] V. D. Bezuglyi and V. N. Dmitrieva, Zhur. Obshchei Khim. 28, 308 (1958).*

[2] Bogert, J. Am. Chem. Soc. 46, 1703 (1913).

* Original Russian pagination. See C. B. translation.

[3] H. Ruppe, A. Braun, and K. Zimbrowski, Ber. 34, 3522 (1901).

[4] L. Weil, Monatsh. 29, 906 (1909).

[5] A. Bauer and F. Bloem, Ber. 17, 964 (1884); 15, 2153 (1882).

[6] H. Gevekaut, Ber. 15, 2087 (1882).

AROMATIC HYDROCARBONS

XII. ADDUCTS OF 1,3-ALKADIENES WITH 1-NAPHTHALENEACRYLIC ACID

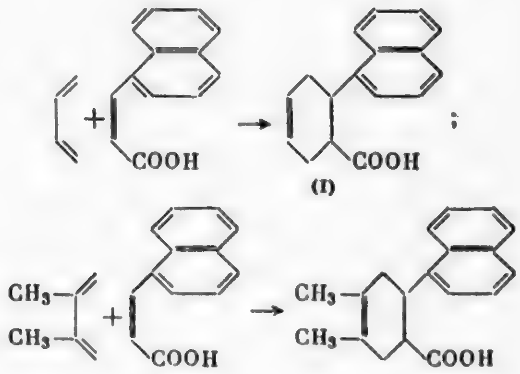
V. R. Skvarchenko, R. Ya. Levina, and M. I. Pugina

Moscow State University

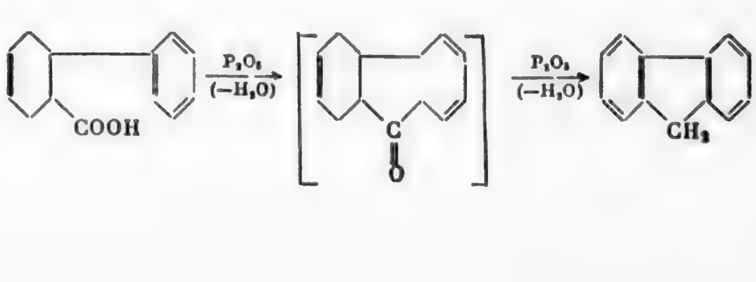
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 46-50, January, 1960

Original article submitted December 19, 1958

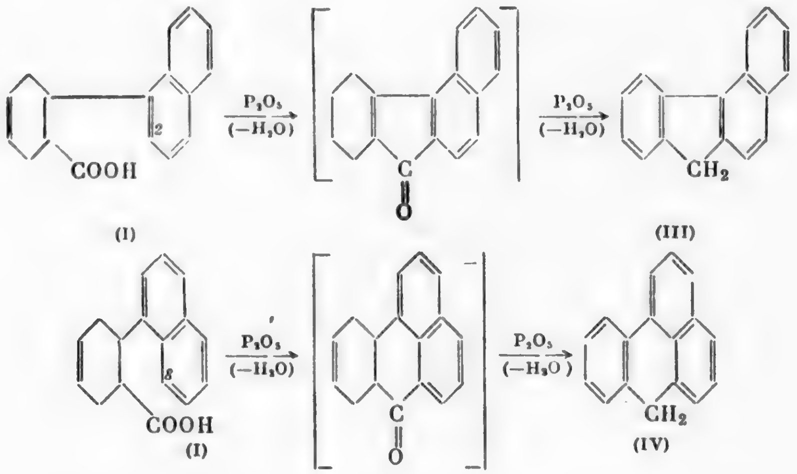
A study of 1-naphthaleneacrylic acid in the diene synthesis reaction has not been made up to now. In the present paper it was shown that this dienophile is less reactive than the structural analogous cinnamic acid, and in order to obtain adducts of 1-naphthaleneacrylic acid with dienic hydrocarbons, it is necessary to heat for a long time at elevated temperature in an autoclave. Thus, when 1-naphthaleneacrylic acid was heated with butadiene and 2,3-dimethyl-1,3-butadiene in an autoclave for 30 and 14 hours, respectively, at 150-160° and 180-190°, we obtained 2-(1-naphthyl)- (I) and 4,5-dimethyl-2-(1-naphthyl)- (II) - 1,2,3,6-tetrahydrobenzoic acids in yields of 27 and 53%, respectively.



As we had reported earlier [1], the adducts of 1,3-alkadienes with cinnamic acid, namely 2-phenyl-1,2,3,6-tetrahydrobenzoic acids, are converted into hydrocarbons of the fluorene series when heated with phosphorus pentoxide; for example



It could be expected that the reaction of phosphorus pentoxide with the adduct of butadiene and 1-naphthaleneacrylic acid (I) would go in a similar manner. However, the intramolecular acylation of the naphthalene ring by the carboxyl group (first stage of the reaction) could proceed in two directions – either in position 2 or 8 of the naphthalene ring; here the formation of a mixture of two hydrocarbons (or of only one of them) could be expected, namely 3,4-benzofluorene (III) and benzanthracene (IV).



From the products of reacting phosphorus pentoxide with adduct (I) we isolated a hydrocarbon, the physical and chemical properties of which differed from those of 3,4-benzofluorene (III), but proved to be close to the properties of benzanthracene (IV) (Table).

Hydrocarbon	Melting point	Melting point	
		of picrate	of dibromide
Obtained hydrocarbon	72°	110°	173°
3,4-Benzofluorene (III) [2]	124–125	130–131	Does not form a dibromide
Benzanthracene (IV) [3]	81	111	174

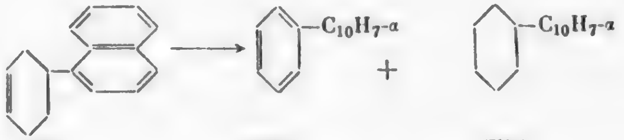
However, the mixed melting point of the obtained hydrocarbon with authentic benzanthracene was depressed considerably; the mixed melting point of the picrates of the two hydrocarbons was also depressed. That the obtained hydrocarbon is different from benzanthracene was also confirmed by making a comparative study of the infrared absorption spectra of the two hydrocarbons (Figure).*

Further study revealed that carbon dioxide is evolved when the adduct of butadiene with 1-naphthaleneacrylic acid is reacted with phosphorus pentoxide. The decarboxylation of 2-(1-naphthyl)-1,2,3,6-tetrabenzoic acid (I) should lead to the formation of 1-(Δ^3-cyclohexenyl)naphthalene (V). The latter is not reported in the literature; only the isomeric hydrocarbon with the double bond in a different position is known, namely 1-(Δ^1-

* We wish to thank L. A. Kazitsina for taking the infrared absorption spectra.

cyclohexenyl)naphthalene, which when heated with selenium suffers irreversible catalysis with the formation of 1-phenylnaphthalene (VI) and 1-cyclohexylnaphthalene (VII); of these two hydrocarbons only the second (VII) forms a picrate [4].

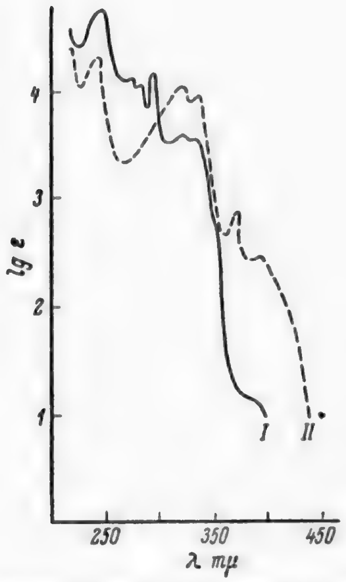
To identify the hydrocarbon obtained by us as being 1-(Δ^3-cyclohexenyl)naphthalene we heated our compound with selenium and found that it also was converted to a mixture of 1-phenyl- (VI) and 1-cyclohexylnaphthalene (VII).



(V) (VI) (VII)

From the products of this reaction we obtained a picrate, which had the same melting point as the earlier described picrate of 1-cyclohexylnaphthalene [4]; the mixed melting point with the specially synthesized picrate of 1-cyclohexylnaphthalene was not depressed.

As a result, 2-(1-naphthyl)-1,2,3,6-tetrahydrobenzoic acid [the adduct of butadiene with 1-naphthaleneacrylic acid (I)] when reacted with phosphorus pentoxide yields 1-(Δ^3-cyclohexenyl)-naphthalene (and not benzanthracene or 3,4-benzofluorene), cleaving carbon dioxide, i.e., it behaves differently than 2-phenyl-1,2,3,6-tetrahydrobenzoic acid (adduct of butadiene with cinnamic acid), which under the same conditions is converted to fluorene, cleaving water.



Absorption spectra (in methyl alcohol) of obtained hydrocarbon (I) and benzanthracene (II).

I: λ_{max} 257, lg ε_{max} 4.76; λ_{max} 279, lg ε_{max} 4.10; λ_{max} 290, lg ε_{max} 4.03; λ_{max} 302, lg ε_{max} 4.15; λ_{max} 329, lg ε_{max} 3.60; λ_{max} 345, lg ε_{max} 3.51;

II: λ_{max} 228, lg ε_{max} 4.39; λ_{max} 250, lg ε_{max} 4.30; λ_{max} 328, lg ε_{max} 4.01; λ_{max} 344, lg ε_{max} 3.92; λ_{max} 375, lg ε_{max} 2.86; λ_{max} 400, lg ε_{max} 2.42.

EXPERIMENTAL

Preparation of adducts of dienic hydrocarbons with 1-naphthaleneacrylic acid. 2-(1-Naphthyl)-1,2,3,6-tetrahydrobenzoic acid (I) (not described in the literature) was obtained by heating 1-naphthaleneacrylic acid* (m. p. 204-205°; 32.6 g, 0.165 mole) with excess butadiene (50 ml, 0.7 mole) in benzene (25 ml), in the presence of hydroquinone (1 g), in an autoclave at 140-150° for 30 hours. The isolated precipitate (16 g), representing a mixture of starting acid and formed adduct, was extracted with light benzine to remove the adduct. The solvents were distilled from the combined benzene and benzine solutions, while the residue was treated with 2 N sodium carbonate solution. The sodium carbonate solution was acidified with 2 N hydrochloric acid, and the precipitated adduct was recrystallized from light benzine; m. p. 113° (yield 10.5 g, 27%). Judging from the analysis, the compound was contaminated with starting 1-naphthaleneacrylic acid.**

Found %: C 80.10, 80.08; H 6.30, 6.43. $C_{17}H_{16}O_2$. Calculated %: C 80.92; H 6.39.

4,5-Dimethyl-2-(1-naphthyl)-1,2,3,6-tetrahydrobenzoic acid (II) (not described in the literature) was obtained by heating 1-naphthaleneacrylic acid (16.5 g, 0.083 mole) with 2,3-dimethylbutadiene (10 g, 0.12 mole) in xylene (100 ml), in the presence of

* 1-Naphthaleneacrylic acid was prepared by the hydrolysis of its ethyl ester, which was obtained by the condensation (in the presence of sodium) of 1-naphthaldehyde with ethyl acetate [5].

** The adduct of butadiene with cinnamic acid could also not be obtained completely free of cinnamic acid [1].

hydroquinone (1 g), in an autoclave at 170-180° for 14 hours. The xylene was removed by vacuum-distillation, while the residue was dissolved in ether and then extracted with 5% sodium carbonate solution. Acidification of the sodium carbonate solution with 2 N hydrochloric acid gave a precipitate of the acid (12.5 g, 53%), which after sublimation and recrystallization from light benzine melted at 156-158°.

Found %: C 81.71, 81.73; H 7.18, 7.13. $C_{19}H_{20}O_2$. Calculated %: C 81.65; H 6.85.

Reaction of 2-(1-naphthyl)-1,2,3,6-tetrahydrobenzoic acid with phosphorus pentoxide. Into a Wurtz flask, fitted with a short air condenser and receiver, was charged the butadiene – 1-naphthaleneacrylic adduct * (I) (5.7 g, 0.022 mole) and phosphorus pentoxide (4.7 g, 0.022 mole); the reaction mixture was heated gradually in vacuo (10 mm), in which connection the reaction product was distilled off as fast as it was formed. The obtained hydrocarbon (2.95 g, 61%) was recrystallized from butyl alcohol, then dissolved in benzene, and the dark benzene solution was passed through a column filled with aluminum oxide. After distilling off the benzene, the residue was purified first by sublimation, and then by recrystallization from alcohol. The isolated 1-(Δ^3-cyclohexenyl)naphthalene melted at 72°; picrate, m. p. 110° (from alcohol). Treatment of the compound with a 10% solution of bromine in acetic acid [4] gave the dibromide with m. p. 173° (from alcohol). The literature data for the other two possible reaction products, namely benzanthracene and 3,4-benzofluorene, and their derivatives (picrate and dibromide), are given above. The mixed melting point of the obtained 1-(Δ^3-cyclohexenyl)naphthalene (m. p. 72°) with benzanthracene (m. p. 81°), and also the mixed melting point of their picrates (m. p. 173° and 174°, respectively), were both depressed (the mixed melting point of the two hydrocarbons was 58-59°, while the mixed melting point of the two picrates was 81-82°).

A mixture of 0.4 g of 1-(Δ^3-cyclohexenyl)naphthalene (V) and 0.4 g of selenium was heated for 24 hours in a metal bath at 300-320°. The reaction product was extracted with alcohol, and the addition of an alcohol solution of picric acid to the extract gave a picrate with m. p. 123°; the mixed melting point of this picrate with the picrate of 1-cyclohexylnaphthalene, obtained by counter synthesis,** was not depressed.

SUMMARY

1. We were the first to investigate 1-naphthaleneacrylic acid as a dienophile in the diene synthesis; its adducts with butadiene and 2,3-dimethyl-1,3-butadiene were obtained.

2. It was shown that 2-(1-naphthyl)-1,2,3,6-tetrahydrobenzoic acid (adduct of butadiene with 1-naphthylacrylic acid) cleaves carbon dioxide when reacted with phosphorus pentachloride and yields 1-(Δ^3-cyclohexenyl)-naphthalene, i.e., it behaves differently than the structurally analogous 2-phenyl-1,2,3,6-tetrahydrobenzoic acid (adduct of butadiene with cinnamic acid), which under the same conditions cleaves water and is converted to fluorene.

LITERATURE CITED

[1] R. Ya. Levina, V. R. Skvarchenko, L. A. Chervoneva, L. V. Fedorchuk, and T. T. Vasil'eva, Doklady Akad. Nauk SSSR 118, 938 (1958). ***

[2] J. Cook, A. Dansi, C. Hewett, J. Iball, W. Mayneord, and E. Roe, J. Chem. Soc. (1935), 1319.

* The adduct was contaminated with 1-naphthaleneacrylic acid, but as a special experiment revealed, all of the 1-naphthaleneacrylic acid is converted to a tar when reacted with phosphorus pentachloride under the conditions employed by us.

** Reaction of cyclohexanone with 1-naphthylmagnesium bromide gave 1-(Δ^1-cyclohexenyl)naphthalene [4], which was then heated with selenium for 24 hours at 300-320°. The reaction product was extracted with alcohol, and then an alcohol solution of picric acid was added to it. The obtained 1-cyclohexylnaphthalene picrate melted at 123°, which agrees with the literature [4].

*** Original Russian pagination. See C. B. translation.

[3] O. Bally and R. Scholl, Ber. 44, 1656 (1911).

[4] J. Cook, C. Hewett, and C. Lawrence, J. Chem. Soc. (1936), 71.

[5] S. I. Sergievskaya, K. V. Levshina, and E. N. Petrova, Zhur. Obshchei Khim. 20, 1478 (1950).*

* Original Russian pagination. See C. B. translation.

AROMATIC HYDROCARBONS

XIII. SYNTHESIS OF FLUORENES FROM ADDUCTS OF 1,2-INDENEDICARBOXYLIC ANHYDRIDE

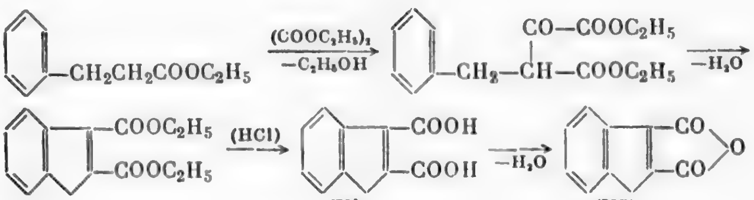
V. R. Skvarchenko, L. A. Chervoneva, and R. Ya. Levina

Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 50-54, January, 1960

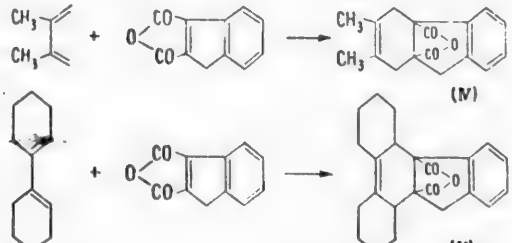
Original article submitted January 22, 1959

In previous papers we investigated the action of phosphorus pentoxide on the adducts of diene hydrocarbons with the cyclic analogs of maleic anhydride (1,2-Δ^1-cyclohexenedicarboxylic and 1,2-Δ^1-cyclopentenedicarboxylic anhydrides), leading to the formation of hydrocarbons of the tetralin [1] and indan [2] series. In the present paper we studied the behavior of the adducts of dienic hydrocarbons with 1,2-indenedicarboxylic anhydride in the same reaction, in which connection we were the first to use the latter compound as a dienophile in the diene synthesis reaction. The starting material used to obtain this dienophile was the ethyl ester of hydrocinnamic acid, from which through the intermediate stage of synthesizing diethyl 1,2-indenedicarboxylate (I) * we obtained 1,2-indenedicarboxylic acid (II), and then the anhydride (III).



(I) (II) (III)

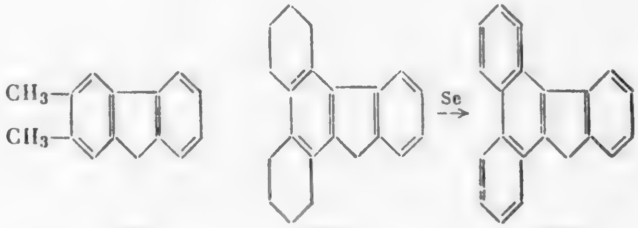
The reaction of 1,2-indenedicarboxylic anhydride (III) with 2,3-dimethyl-1,3-butadiene (heating in an autoclave at 120° for 30 hours) and with 1,1'-bicyclohexenyl (refluxing in xylene solution for 40 hours) gave 2,3-dimethyl-1,4,10,11-tetrahydro-10,11-fluorenedicarboxylic anhydride (IV) and 1,2,3,4-dicyclohexano-1,4,10,11-tetrahydro-10,11-fluorenedicarboxylic anhydride (V) in 84 and 67.5% yield, respectively.



(IV) (V)

* To obtain diethyl 1,2-indenedicarboxylate (I) we worked out a method in which ethyl hydrocinnamate was condensed with diethyl oxalate, followed by cyclization of the reaction product using concentrated sulfuric acid (the preparation of diethyl indenedicarboxylate is mentioned in [3], but the reaction conditions and the yield are not given).

The behavior of the adducts of 1,2-indenedicarboxylic anhydride when reacted with phosphorus pentoxide proved to be similar to the behavior of the adducts of 1,2-Δ^1-cyclohexenedicarboxylic and 1,2-Δ^1-cyclopentene-dicarboxylic anhydrides in the same reaction: the reaction went with the evolution of carbon monoxide and led to the formation of the corresponding aromatic hydrocarbons, namely fluorenes. The heating of adducts (IV) and (V) with phosphorus pentoxide gave 2,3-dimethylfluorene (VI) and 1,2,3,4-dicyclohexanofluorene (VII), respectively; the latter was identified by its conversion to 1,2,3,4-dibenzofluorene (VIII):



(VI) (VII) (VIII)

The isolated hydrocarbons proved to be identical with the fluorenes that we had obtained earlier by a different type of reaction, namely, by the action of phosphorus pentoxide on the adducts formed from 2,3-dimethylbutadiene and 1,1'-bicyclohexenyl with cinnamic acid, which went without the evolution of carbon monoxide [4].

EXPERIMENTAL

Synthesis of 1,2-indenedicarboxylic anhydride. a) Diethyl 1,2-indenedicarboxylate (I). Diethyl oxalate (115 g) was added to 18.2 g of sodium in 350 ml of absolute ether; then ethyl hydrocinnamate (140 g, b. p. 124° at 12 mm; obtained by the esterification of hydrocinnamic acid * in the presence of sulfuric acid; literature data [5]: b. p. 110-112° at 8 mm) was added dropwise in 1.5 hours. After vigorous reaction had ceased, the mixture was allowed to stand overnight, after which it was cooled in ice and decomposed with dilute sulfuric acid (50 ml of concentrated sulfuric acid in 500 ml of water), cooled to 0°, until the ether layer became colorless (the decomposition was stopped when the dark red ether solution became light yellow). The ether layer was washed with water, dried over sodium sulfate, and the ether distilled off (in vacuo); the residue was poured into 1200 ml of concentrated sulfuric acid (cooled to − 5°) at such a rate that the temperature of the reaction mass did not exceed 5-10°. After standing in the cold for 2 hours, the reaction mixture was poured in small portions over ice (3 kg); the diethyl indenedicarboxylate (I) deposited here, and was purified by recrystallization from petroleum ether; m. p. 76-77°. The yield was 68 g (31%). Literature data [3]: m. p. 78°.

b) The diethyl indenedicarboxylate (68 g) was refluxed with 500 ml of concentrated hydrochloric acid for 4 hours; the 1,2-indenedicarboxylic acid (II, 52 g, 97%) crystallized from the hot solution, and after recrystallization from water melted with decomposition at 215-217°. Literature data [3]: m. p. 215° (decomp.).

c) 1,2-Indenedicarboxylic anhydride (III) was obtained from the indenedicarboxylic acid (46.5 g) by refluxing with acetyl chloride (470 ml) for 10 hours (until all of the acid had dissolved). After distilling off the acetyl chloride (in vacuo), the residue was recrystallized from alcohol. The anhydride crystallized with one molecule of alcohol.** Yield 23.1 g (43%), m. p. 184-185°. The compound is new.

* Hydrocinnamic (β-phenylpropionic) acid was obtained in quantitative yield by the reduction of cinnamic acid with amalgamated zinc in hydrochloric acid: m. p. 47-48° (from water). Literature data [6]: m. p. 48°.

** Based on the analysis data, the obtained compound can be assigned the structure of the monoethyl ester of 1,2-indenedicarboxylic acid. However, the adducts of this dienophile with dimethylbutadiene and with bicyclohexenyl proved to be the anhydrides of the corresponding acids.

Found %: C 67.15, 67.28; H 5.29, 5.34. $C_{11}H_6O_3 \cdot C_2H_6O$. Calculated %: C 67.23; H 5.21.

Adducts of diene hydrocarbons with 1,2-indenedicarboxylic anhydride. Adduct with 2,3-dimethyl-1,3-butadiene (IV). A mixture of the indenedicarboxylic anhydride (7 g; 0.038 mole), dimethylbutadiene (6.5 g; 0.08 mole) and hydroquinone (0.1 g) was heated in an autoclave at 120° for 30 hours. The reaction mixture crystallized on standing; recrystallization from a mixture of alcohol and ethyl acetate gave 8.5 g (84%) of the adduct – the anhydride of 2,3-dimethyl-1,4,10,11-tetrahydro-10,11-fluorenedicarboxylic acid (new in the literature); m. p. 118-119°.

Found %: C 76.24, 76.25; H 6.13, 6.20. $C_{13}H_{16}O_3$. Calculated %: C 76.10; H 6.01.

Adduct with 1,1'-bicyclohexenyl (V). A mixture of the indenedicarboxylic anhydride (10 g; 0.054 mole) and 1,1'-bicyclohexenyl (8.8 g; 0.054 mole) in 10 ml of xylene was heated in the presence of hydroquinone (0.1 g) for 40 hours at 150°. The xylene was distilled off (in vacuo), and the solid residue was recrystallized to give 12.7 g (67.5%) of the adduct – the anhydride of 1,2,3,4-dicyclohexano-1,4,10,11-tetrahydro-10,11-fluorenedicarboxylic acid (new in the literature); m. p. 163-164° (from a mixture of alcohol and ethyl acetate).

Found %: C 79.53, 79.57; H 6.80, 6.99. $C_{23}H_{24}O_3$. Calculated %: C 79.28; H 6.94.

Action of phosphorus pentoxide on adducts (IV) and (V). Preparation of hydrocarbons of fluorene series. 2,3-Dimethylfluorene (VI). A mixture of the adduct of 2,3-dimethyl-1,3-butadiene (5.7 g) and phosphorus pentoxide (3 g) was heated in a Wurtz flask in a metal bath at 160° for 1 hour; to complete the reaction, the temperature of the bath was then raised to 350°. When the evolution of carbon monoxide had ceased, the hydrocarbon was distilled from the reaction mixture at 195-210° (13 mm), after which it was purified further by recrystallization from alcohol. We obtained 3.1 g (75%) of 2,3-dimethylfluorene with m. p. 123-124° (from alcohol); picrate, m. p. 105-106° (from alcohol). Literature data [4]: m. p. 123.5-124.5°; picrate, m. p. 105-106°. The mixed melting point with the 2,3-dimethylfluorene obtained by a counter synthesis (action of phosphorus pentoxide on the adduct of the 2,3-dimethylbutadiene with cinnamic acid) was not depressed; the mixed melting point of the picrates was also not depressed.

1,2,3,4-Dicyclohexanofluorene (VII). A mixture of the 1,1'-bicyclohexenyl adduct (10 g) and phosphorus pentoxide (4.1 g) was heated in a flask with "sabers" in a metal bath, the temperature of which was raised (in 4 hours) from 180 to 320°. After the evolution of carbon monoxide had ceased, the reaction product was distilled at 260-280° (11 mm). The viscous mass was recrystallized from petroleum ether to give 6 g (76%) of 1,2,3,4-dicyclohexanofluorene; m. p. 128-128.5° (from either petroleum ether or n-butyl alcohol). Literature data [4]: m. p. 129-129.5°. The mixed melting point with the 1,2,3,4-dicyclohexanofluorene obtained by a different route (action of phosphorus pentoxide on the adduct of 1,1'-bicyclohexenyl with cinnamic acid) was not depressed.

1,2,3,4-Dicyclohexanofluorene (1 g) was heated with selenium (1.2 g) for 4 hours at 340-350°. The reaction mass was extracted with boiling n-butyl alcohol; the solution on cooling deposited 1,2,3,4-dibenzofluorene (VIII; 0.4 g; 41%): m. p. 158-159° (from n-butyl alcohol); picrate, m. p. 153-153.5° (from n-butyl alcohol). Literature data [4]: m. p. 159-159.5°; picrate, m. p. 153-154°. The mixed melting points with both the authentic dibenzofluorene and its picrate were not depressed.

SUMMARY

1. The anhydride of 1,2-indenedicarboxylic acid was used for the first time as a dienophile in the diene synthesis. Its adducts with 2,3-dimethyl-1,3-butadiene and 1,1'-bicyclohexenyl were synthesized.

It was shown that the reaction between phosphorus pentoxide and the adducts of 1,2-indenedicarboxylic anhydride with dienic hydrocarbons (2,3-dimethyl-1,3-butadiene and 1,1'-bicyclohexenyl) proceeds with the evolution of carbon monoxide and water, and leads to the formation of hydrocarbons of the fluorene series (2,3-dimethylfluorene and 1,2,3,4-dicyclohexanofluorene, respectively).

LITERATURE CITED

[1] V. R. Skvarchenko, R. Ya. Levina, and L. A. Chervoneva, Vestnik Moskov. Gosudarst. Univ. Khimiya 5, 177 (1957); 5, 187 (1958).

[2] V. R. Skvarchenko, L. A. Chervoneva, I. S. Pastukhova, and R. Ya. Levina, Zhur. Obshchei Khim. 29, 2174 (1959).*

[3] J. Bougault, Compt. rend. 159, 745 (1915).

[4] R. Ya. Levina, V. R. Skvarchenko, L. A. Chervoneva, L. V. Fedorchuk, and T. T. Vasil'eva, Doklady Akad. Nauk SSSR 118, 938 (1958).*

[5] S. P. Lagerev, Zhur. Obshchei Khim. 5, 517 (1935).

[6] M. Conrad, Ann. 204, 174 (1880).

* Original Russian pagination. See C. B. translation.

AROMATIC HYDROCARBONS

XIV. ACTION OF PHOSPHORUS PENTOXIDE ON THE ADDUCTS OF DIENE HYDROCARBONS WITH THE ANHYDRIDE OF 3,4-DIHYDRO-1,2-NAPHTHALENEDICARBOXYLIC ACID

V. R. Skvarchenko, L. A. Chervoneva, V. A. Puchnova, and R. Ya. Levina

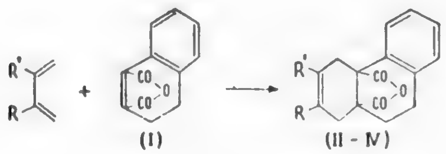
Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 54-59, January, 1960

Original article submitted January 22, 1959

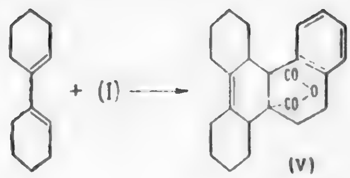
In previous papers [1] we had investigated the action of phosphorus pentoxide on the anhydrides of tetrahydrophthalic acids (adducts of diene hydrocarbons with maleic anhydride), proceeding with the evolution of carbon monoxide and water and leading to the formation of aromatic hydrocarbons. Utilization of the adducts of diene hydrocarbons with the cyclic analogs of maleic anhydride, namely the anhydrides of 1-cyclohexene-1,2-dicarboxylic and 1-cyclopentene-1,2-dicarboxylic acids, made it possible to use this reaction as a method for the synthesis of hydrocarbons of the tetralin [2] and indan [3] series.

In this paper we used the anhydride of 3,4-dihydro-1,2-naphthalenedicarboxylic acid (I) as the dienophile; the adducts of this dienophile with butadiene – the anhydride of 1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic acid (II), with isoprene – the anhydride of 3-methyl-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic acid (III), and with 2,3-dimethyl-1,3-butadiene – the anhydride of 2,3-dimethyl-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic acid (IV), were obtained in yields of 40, 79.5 and 72%, respectively.

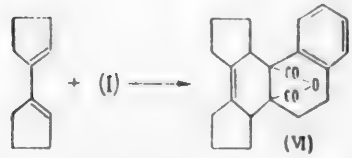


(II) R = R' = H ; (III) R = H , R' = CH_3 ; (IV) R = R' = CH_3 .

We also obtained the adducts of 3,4-dihydro-1,2-naphthalenedicarboxylic anhydride with the following bicyclic diene hydrocarbons: with 1,1'-bicyclohexenyl – the anhydride of 1,2,3,4-dicyclohexano-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic acid (V) (50% yield), and with 1,1'-bicyclopentenyl – the anhydride of 1,2,3,4-dicyclopentano-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic acid (VI) (85% yield).

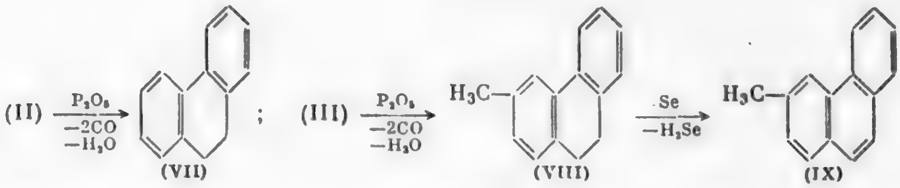


(V)



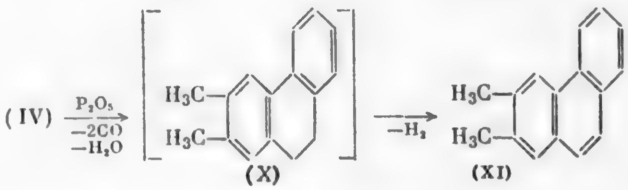
(VI)

Reaction between phosphorus pentoxide and the butadiene adduct (II), which was run with a gradual elevation of the temperature of the reaction mixture from 200 to 300°, gave 9,10-dihydrophenanthrene (VII) in 72% yield.



The heating (200-320°) of the isoprene adduct (III) with phosphorus pentoxide gave 3-methyl-9,10-dihydrophenanthrene (VIII) (69% yield), which was identified by its conversion to 3-methylphenanthrene (IX) when heated with selenium.

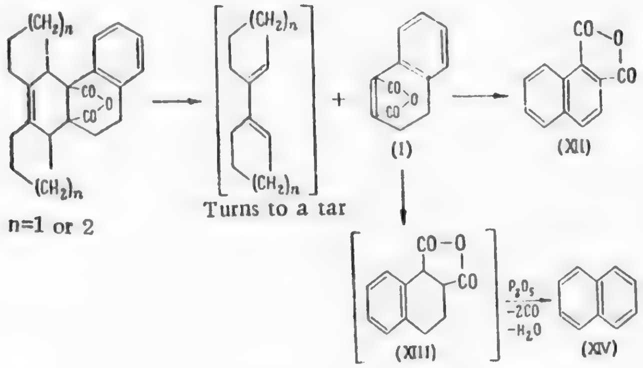
The heating (250-350°) of the 2,3-dimethyl-1,3-butadiene adduct (IV) with phosphorus pentoxide for 6 hours gave, instead of the expected 2,3-dimethyl-9,10-dihydrophenanthrene (X), only the corresponding dehydrogenation product, namely 2,3-dimethylphenanthrene (XI) (39% yield); this hydrocarbon is formed by the removal of the labile hydrogen atoms in the 9 and 10 positions of the normal reaction product, namely 2,3-dimethyl-9,10-dihydrophenanthrene (X).



As a result, a combination of long heating and raising the temperature of the reaction mixture to 350° led to the appearance of a secondary reaction — the dehydrogenation of the normal reaction products (dihydrophenanthrenes).

Adducts (V) and (VI) proved to be the most stable to the action of phosphorus pentoxide; their decomposition was run at 300-400° for 10 hours; however, the 1,2,3,4-dicyclohexano- and, correspondingly, 1,2,3,4-dicyclopentano-9,10-dihydrophenanthrenes (or the corresponding phenanthrene hydrocarbons) were not found in the reaction products. Only the anhydride of 1,2-naphthalenedicarboxylic acid (XII) and naphthalene were obtained from both adducts. It is possible to explain the formation of these compounds in the following manner: at high temperature (300-400°) the adducts decompose into starting diene (which is converted to tar by the phosphorus pentoxide) and dienophile — the anhydride of 3,4-dihydro-1,2-naphthalenedicarboxylic acid (I); the latter is converted (by reactions of the irreversible catalysis type) into a mixture of 1,2-naphthalenedicarboxylic anhydride (XII), not changing further and appearing as one of the reaction products, and 1,2,3,4-tetrahydro-1,2-naphthalenedicarboxylic anhydride (XIII), which under the influence of phosphorus pentoxide

undergoes the usual aromatization reaction, cleaving carbon monoxide and water and suffering change to naphthalene (second reaction product).



In a control experiment the heating of 3,4-dihydro-1,2-naphthalenedicarboxylic anhydride (I) with an equimolar amount of phosphorus pentoxide at 360° gave the same reaction products, namely 1,2-naphthalenedicarboxylic anhydride (XII) and naphthalene (XIV).

EXPERIMENTAL

Preparation of adducts of diene hydrocarbons with the anhydride of 3,4-dihydro-1,2-naphthalenedicarboxylic acid. Butadiene adduct (II). A mixture of butadiene (141 ml; 1.58 moles) and 3,4-dihydro-1,2-naphthalenedicarboxylic anhydride (I) (50 g; 0.26 mole; m. p. 124-125°; obtained by the condensation of ethyl γ-phenylbutyrate with diethyl oxalate and subsequent cyclization of the condensation product [4]) was heated for 80 hours, in the presence of hydroquinone (0.2 g), in an autoclave at 100-120°. The obtained oily reaction product was vacuum-distilled. Here we isolated 1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic anhydride (II, 25 g, 40%, b. p. 160-170° at 1 mm), which crystallized when placed in the refrigerator and had m. p. 82-83°; after recrystallization from a mixture of benzene and ligroine, m. p. 83-84°. Literature data [5]: m. p. 83.5 to 84°.

Isoprene adduct (III). A mixture of the dihydronaphthalenedicarboxylic anhydride (15 g; 0.075 mole), isoprene (15 ml; 0.15 mole; b. p. 32.5 at 745 mm) and hydroquinone (0.1 g) was heated in an autoclave at 160-170° for 30 hours. Vacuum-distillation of the reaction mass gave a fraction with b. p. 200-220° (10 mm), which slowly crystallized when placed in the refrigerator. Recrystallization from anhydrous alcohol gave 3-methyl-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic anhydride (III), 16 g (79.5%), m. p. 141-141.5°, not reported in the literature.

Found %: C 76.26, 76.30; H 6.14, 6.15. $C_{17}H_{16}O_3$. Calculated %: C 76.10; H 6.01.

2,3-Dimethyl-1,3-butadiene adduct (IV). A mixture of the dihydronaphthalenedicarboxylic anhydride (22 g; 0.11 mole) and 2,3-dimethyl-1,3-butadiene (20 g; 0.24 mole; b. p. 67-68° at 754 mm) was heated in the presence of hydroquinone (0.1 g) for 30 hours in an autoclave at 100-120°. Vacuum-distillation of the reaction product gave a fraction with b. p. 180-200° (2 mm), which slowly crystallized on standing and was 2,3-dimethyl-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic anhydride (IV), 22.4 g (72%), m. p. 76-77° (from petroleum ether). Literature data [6]: m. p. 76-77°.

1,1'-Bicyclohexenyl adduct (V). A mixture of the dihydronaphthalenedicarboxylic anhydride (13.2 g; 0.066 mole), 1,1'-bicyclohexenyl (10.7 g; 0.066 mole; b. p. 123-124° at 15 mm; $n^{20}D$ 1.5320 [7]) and hydroquinone (0.1 g) was heated in 10 ml of xylene, with mechanical stirring, for 35 hours. The 1,2,3,4-dicyclohexano-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic anhydride (V, 12 g, 50%, not reported in the literature) that deposited when the reaction mixture was cooled had m. p. 186-187° (from a mixture of alcohol and xylene).

Found %: C 79.60, 79.72; H 7.23, 7.40. $C_{24}H_{26}O_3$. Calculated %: C 79.52; H 7.23.

1,1'-Bicyclopentenyl adduct (VI) was obtained in the same manner as the 1,1'-bicyclohexenyl adduct. From 15 g of the dihydronaphthalenedicarboxylic anhydride and 10 g of 1,1'-bicyclopentenyl (b. p. 81-82° at 10 mm, $n^{20}D$ 1.5235 [8]) we obtained 21.2 g (85%) of 1,2,3,4-dicyclopentano-1,4,9,10,11,12-hexahydro-11,12-phenanthrenedicarboxylic anhydride (VI), not reported in the literature, m. p. 164-165° (from a mixture of alcohol and xylene).

Found %: C 79.06, 78.93; H 6.68, 6.65. $C_{22}H_{22}O_3$. Calculated %: C 79.01; H 6.63.

Action of phosphorus pentoxide on the adducts of diene hydrocarbons with the anhydride of 3,4-dihydro-1,2-naphthalenedicarboxylic acid. The adducts of butadiene and its homologs (II – IV) were heated with an equimolar amount of phosphorus pentoxide in a metal bath, the temperature of which was gradually raised from 200 to 300° (for adduct II) and from 320 to 350° (for adducts III and IV). After the evolution of gas had ceased the reaction product was vacuum-distilled, after which it was dissolved in petroleum ether, heated with 20% NaOH solution (to remove traces of starting adduct), washed with water, dried over calcium chloride, and after distilling off the petroleum ether the product was vacuum-distilled again.

a) From the butadiene adduct (II; 15 g) we obtained a fraction with b. p. 230-250° (1 mm), which crystallized on standing in the refrigerator. The 9,10-dihydrophenanthrene (VII) isolated in this manner (7.7 g, 72%) had m. p. 33-34.5° (from methyl alcohol). Literature data [9]: m. p. 35°.

9,10-Dihydrophenanthrene was identified by its dehydrogenation to phenanthrene, and this was accomplished by heating it with sulfur for 8 hours at 210-220°. The obtained phenanthrene was vacuum-sublimed, m. p. 98-99°; picrate, m. p. 144-144.5° (from alcohol). The mixed melting points with authentic phenanthrene and its picrate were not depressed. Literature data [10]: m. p. 100°; picrate, m. p. 145°.

b) From the isoprene adduct (III, 8 g) we obtained 3-methyl-9,10-dihydrophenanthrene (VIII); 4 g (69%).

B. p. 167-168° (9 mm); $n^{20}D$ 1.6309; d^{20}_4 1.0663, MR_D 64.89. $C_{15}H_{14}F_6$. Calculated: MR_D 62.07; EM_D 2.82.

Found %: C 92.47, 92.45; H 7.73, 7.62. $C_{15}H_{14}$. Calculated %: C 92.74; H 7.26.

Analysis of the gas evolved during reaction revealed that, besides carbon monoxide, it also contained a small amount of carbon dioxide (CO 91.4%, CO_2 8.6%), the formation of which must be explained by the partial decarboxylation of the starting adduct (III) to 3-methyl-1,4,9,10,11,12-hexahydrophenanthrene. Judging from the analysis, traces of this hexahydrophenanthrene were present in the 3-methyl-9,10-dihydrophenanthrene obtained by us.

The obtained hydrocarbon (1.9 g) was heated with selenium (1 g) for 4 hours at 310-320°. The dehydrogenation product was vacuum-distilled (at 12 mm), and after recrystallization from alcohol we obtained 3-methylphenanthrene (1.4 g) with m. p. 62-63°; picrate, m. p. 139-140.5° (from alcohol).

Literature data [11]: m. p. 65°; picrate, m. p. 141° (literature data for 2-methylphenanthrene [12]: m. p. 55-56°; picrate, m. p. 118-119°).

c) From the 2,3-dimethyl-1,3-butadiene adduct (IV; 11 g) we obtained 2,3-dimethylphenanthrene (XI), 3.1 g (39%).

B. p. 190-193° (15 mm); m. p. 79-80° (from alcohol).

Found %: C 93.05, 93.03; H 7.09, 7.15. $C_{16}H_{14}$. Calculated %: C 93.13; H 6.87.

Picrate, m. p. 145-146° (from alcohol).

Literature data [5]: m. p. 78-78.5°; picrate, m. p. 146-147°.

Neither the mixed melting point with 2,3-dimethylphenanthrene (obtained by a counter synthesis*) nor that of the picrates was depressed.

The 1,1'-bicyclohexenyl adduct (V; ~ 9 g) was heated with phosphorus pentoxide (3.5 g) in a metal bath for 10 hours with a gradual raising of the temperature from 300 to 390°. A substance (0.4 g) distilled off during reaction, which crystallized on standing and proved to be naphthalene: m. p. 78-79° (from alcohol).

Found %: C 93.35, 93.64; H 6.50, 6.50. $C_{10}H_8$. Calculated %: C 93.71; H 6.29.

Picrate, m. p. 148-149° (from alcohol).

Literature data: m. p. 80.3° [13]; picrate, m. p. 149° [14].

The mixed melting points with authentic naphthalene and its picrate were not depressed.

Vacuum-sublimation of the reaction mass gave a second reaction product, the anhydride of 1,2-naphthalenedicarboxylic acid (1.1 g), m. p. 167-168° (from a mixture of benzene and ligroine). The imide of 1,2-naphthalenedicarboxylic acid, obtained by fusing the anhydride with urea at 180°, melted at 224° (vacuum-sublimed). Literature data [15]: 1,2-naphthalenedicarboxylic anhydride, m. p. 168°; imide, m. p. 224°. Neither the mixed melting point with 1,2-naphthalenedicarboxylic anhydride, obtained by a counter synthesis [16], nor that of the imides** was depressed.

From the 1,1'-bicyclopentenyl adduct (VI; 10 g) and phosphorus pentoxide (6.2 g), when heated at 290-380° under the conditions described above, we obtained: naphthalene with m. p. 78-78.5° (picrate, m. p. 149-150°), and 1,2-naphthalenedicarboxylic anhydride with m. p. 166-167° (imide, m. p. 224°). The reaction products were identified in the same manner as in the preceding case.

Reaction of 3,4-dihydro-1,2-naphthalenedicarboxylic anhydride with phosphorus pentoxide. The anhydride (1, 8 g) was heated with phosphorus pentoxide (5.4 g) in a metal bath, the temperature of which was raised in 3 hours from 290 to 360°. After evolution of the gas containing carbon monoxide, carbon dioxide, hydrogen and unsaturated hydrocarbons, had ceased, the reaction products were vacuum-sublimed. Here we isolated 0.3 g of naphthalene and 2 g of 1,2-naphthalenedicarboxylic anhydride.

SUMMARY

1. The action of phosphorus pentoxide at 200-320° on the adducts of 3,4-dihydro-1,2-naphthalenedicarboxylic anhydride with butadiene and isoprene leads to the formation of 9,10-dihydrophenanthrene and 3-methyl-9,10-dihydrophenanthrene.

2. The action of phosphorus pentoxide at 200-350° on the adduct of 3,4-dihydro-1,2-naphthalenedicarboxylic anhydride with 2,3-dimethyl-1,3-butadiene proceeds with the further dehydrogenation of the normal reaction product (2,3-dimethyl-9,10-dihydrophenanthrene) and the formation of 2,3-dimethylphenanthrene.

3. The studied reaction can be recommended as a method for the synthesis of dihydrophenanthrenes (and of phenanthrenes by the subsequent dehydrogenation of the dihydrophenanthrenes) with alkyl substituents.

---

* A mixture of 5 g of adduct (IV), 9.5 g of KOH and 10 ml of water was heated until the solid K-salt formed, after which, by careful heating, the mixture of water and decarboxylation product was distilled off. The aqueous layer was extracted with ether; the ether extract was dried over calcium chloride, the ether distilled off, and the residue was vacuum-distilled. The obtained hydrocarbon fraction (2.1 g; b. p. 150-165° at 11 mm) was heated with selenium (3 g) for 5 hours at 340°. The reaction mass was extracted with boiling alcohol; the alcohol solution on cooling deposited 2,3-dimethylphenanthrene (1 g): m. p. 78-79°; picrate, m. p. 145-146° (from alcohol).

** Heating 4 g of the dihydronaphthalenedicarboxylic anhydride with 0.7 g of sulfur at 230-240° for 1.5 hours, followed by vacuum-distillation of the dehydrogenation product, gave 2.5 g (63%) of 1,2-naphthalenedicarboxylic anhydride, m. p. 167-167.5° (from a mixture of benzene and ligroine). Imide (obtained in quantitative yield), m. p. 224°.

4. The limits within which the aromatization reaction (under the influence of phosphorus pentoxide) applies to the adducts of diene hydrocarbons with the cyclic analogs of maleic anhydride were determined.

5. The adducts of 3,4-dihydro-1,2-naphthalenedicarboxylic anhydride with isoprene, 1,1'-bicyclohexenyl and 1,1'-bicyclopentenyl are new compounds.

LITERATURE CITED

[1] R. Ya. Levina, V. R. Skvarchenko, V. N. Kostin, and N. S. Kataeva, Doklady Akad. Nauk SSSR 91, 95 (1953); R. Ya. Levina, V. R. Skvarchenko, N. S. Kataeva, and E. G. Treshchova, Zhur. Obshchei Khim. 23, 1998 (1953);* V. R. Skvarchenko, R. Ya. Levina, and O. Yu. Okhlobystin, Doklady Akad. Nauk SSSR 94, 789 (1954); R. Ya. Levina, V. R. Skvarchenko, and T. V. Kostroma, Zhur. Obshchei Khim. 25, 1094 (1955);* V. R. Skvarchenko, R. Ya. Levina, and M. G. Kuz'min, Zhur. Obshchei Khim. 27, 1784 (1957).*

[2] V. R. Skvarchenko, R. Ya. Levina, and L. A. Chervoneva, Vestnik Moskov. Gosudarst. Univ. Khimiya 5, 177 (1957); 5, 187 (1958).

[3] V. R. Skvarchenko, L. A. Chervoneva, I. S. Pastukhova, and R. Ya. Levina, Zhur. Obshchei Khim. 29, 2154 (1959).*

[4] Organic Syntheses [Russian translation], Coll. Vol. II, pp. 53, 56, 95, 511 (1949).

[5] L. F. Fieser and E. B. Hershberg, J. Am. Chem. Soc. 57, 2192 (1935).

[6] L. F. Fieser and E. B. Hershberg, J. Am. Chem. Soc. 57, 1508 (1935).

[7] I. N. Nazarov and I. V. Torgov, Zhur. Obshchei Khim. 22, 228 (1952).*

[8] R. Ya. Levina, V. R. Skvarchenko, and O. Yu. Okhlobystin, Zhur. Obshchei Khim. 25, 1466 (1955).*

[9] F. A. Askew, J. Chem. Soc. (1935), 512.

[10] C. Graebe, Lieb. Ann. 167, 131 (1873).

[11] R. Pschorr, Ber. 39, 3106 (1906).

[12] R. D. Haworth, J. Chem. Soc. (1932), 1125.

[13] F. Francis and F. J. E. Collins, J. Chem. Soc. (1936), 137.

[14] O. L. Baril and E. S. Hauber, J. Am. Chem. Soc. 53, 1087 (1931).

[15] E. F. Bradbrook and R. P. Linstead, J. Chem. Soc. (1936), 1739.

[16] L. F. Fieser and E. B. Hershberg, J. Am. Chem. Soc. 57, 1851 (1935).

* Original Russian pagination. See C. B. translation.

JOINT POLYMERIZATION OF HEXAFLUOROBUTADIENE WITH DIENE COMPOUNDS IN SOLUTION

A. L. Klebanskii and O. A. Timofeev

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 60-67, January, 1960

Original article submitted August 9, 1958

To determine the reactivity of hexafluorobutadiene when compared with other dienic compounds it seemed of interest to study its joint polymerization with a number of the more common diene compounds. As our topic of study we selected the joint polymerization of hexafluorobutadiene with chloroprene, fluoroprene and isoprene. Determination of the joint polymerization constants permits establishing the relationship between the structure of the enumerated diene compounds and the influence of substituents on the reactivity, and it also permits comparing the relative activities in a series of monomers and radicals. In addition, a study of the process of the joint polymerization of these systems of monomers could have definite practical interest for elucidating the influence exerted by hexafluorobutadiene on the change in the properties of the enumerated diene compounds when it is present as one of the components of the copolymer.

EXPERIMENTAL

Experimental procedure. The polymerizations were run in 8 ml graduated glass ampuls (scale of division 0.05 ml). The calculated amount of solvent was charged into a weighed ampul, the ampul was weighed, then the calculated amount of initiator solution was added from a microburet, after which the ampul was cooled in a Dewar flask to − 20°, and weighed again. Then the ampul was connected to the vacuum setup shown in Fig. 1, and the calculated amount of monomer was charged into it from the receptacle containing either chloroprene, fluoroprene or isoprene, each freshly distilled in a stream of pure nitrogen; after this the ampul was disconnected, weighed, and again connected to the vacuum setup, together with the receptacle containing the hexafluorobutadiene, after which the ampul was cooled in a transparent Dewar flask and the calculated amount of hexafluorobutadiene was distilled into it. Before charging the monomers into the ampul, the system was evacuated and filled with oxygen-free nitrogen three times in succession. When all of the ingredients had been loaded into the ampul, it was weighed again, sealed in a dry ice bath, and placed in a water thermostat, in which the temperature was maintained constant to ± 0.15°. The dilatometric method was employed to control the process, for which purpose calibration curves, based on experimental data, were constructed in advance.

To determine the composition, the ampul was cooled, opened, the copolymer precipitated with methanol, purified from impurities, and dried to constant weight. The chloroprene − hexafluorobutadiene copolymers were analyzed for both chlorine and fluorine. The fluoroprene − hexafluorobutadiene copolymers were analyzed for fluorine, carbon and hydrogen [1].

Copolymerization of chloroprene with hexafluorobutadiene. The influence of the main variables on the rate of the joint polymerization process and on the composition of the copolymers formed was determined.

Influence of the nature of the solvent. As can be seen from Fig. 2, the joint polymerization process proceeds most rapidly in polar solvents like chloroform and chlorobenzene. On this basis it is possible to conclude that polar solvents facilitate a better orientation of the molecules, which apparently accelerates the joint polymerization process.

Influence of the solvent concentration. As can be seen from Fig. 3, the concentration of the solvent (benzene) exerts some influence on the rate of the process. The rate of the process decreases as the concentration is increased.

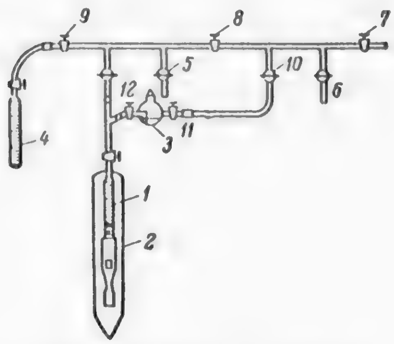


Fig. 1. Scheme for loading monomers into ampul for polymerization. 1) Ampul; 2) transparent Dewar flask; 3) receptacle for monomers (chloroprene, isoprene, fluoroprene); 4) graduated ampul containing hexafluorobutadiene; 5) connection to manometer; 6) tube for nitrogen from purification system; 7) to vacuum pump; 8) stopcocks for connecting or disconnecting different portions of the system during loading.

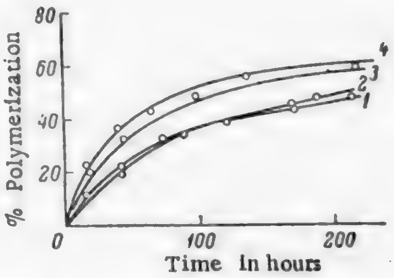


Fig. 2. Relation between the rate of the process and the nature of the solvent. Initiator: isopropylbenzene hydroperoxide (0.6 mole %); monomer : solvent ratio = 1 : 1; starting mole ratio chloroprene : : hexafluorobutadiene = 7.5 : 2.5; temperature 50°. 1) Benzene; 2) carbon tetrachloride; 3) chlorobenzene; 4) chloroform.

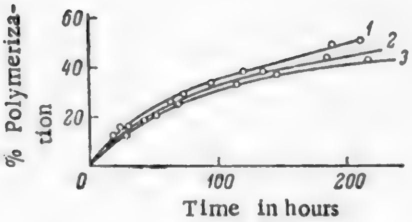


Fig. 3. Relation between the rate of the process and the solvent concentration. Mole ratio chloroprene : hexafluorobutadiene = 7.5 : 2.5; initiator: isopropylbenzene hydroperoxide (0.6 mole %); solvent: benzene; temperature 50°. Monomer: solvent ratio: 1) 1 : 1; 2) 1 : 2; 3) 1 : 3.

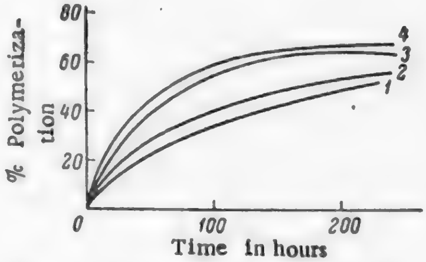


Fig. 4. Relation between the rate of the process and the nature of the initiator. Monomer : benzene ratio = = 1 : 1; temperature 50°; initiator (0.6 mole %): 1) isopropylbenzene hydroperoxide; 2) tert-butylcumene hydroperoxide; 3) azobisisobutyronitrile; 4) benzoyl peroxide.

Influence of the nature of the initiator. As initiators, we tested isopropylbenzene hydroperoxide, tert-butylcumene hydroperoxide, azobisisobutyronitrile and benzoyl peroxide (0.6 mole % based on the monomers). As can be seen from Fig. 4, the most effective initiators are benzoyl peroxide and azobisisobutyronitrile.

Influence of ratio of monomers in starting mixture on the rate of the joint polymerization process and the composition of the copolymers. The following molar ratios of chloroprene to hexafluorobutadiene in the starting mixture were examined: 7.5 : 2.5, 5.0 : 5.0, and 2.5 : 7.5. From Fig. 5 it can be seen that the joint polymerization rate depends on the starting ratio of the monomers. The rate of the process decreases as the amount of hexafluorobutadiene in the starting mixture is increased. The starting ratio of the monomers also exerts an influence on the composition of the copolymers formed. The greater the amount of hexafluorobutadiene in the starting mixture of monomers, the greater is its amount in the copolymer (Fig. 6).

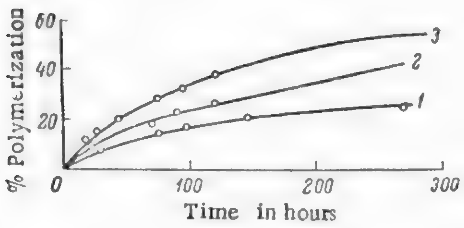


Fig. 5. Relation between the rate of the process and the starting ratio of monomers. Monomer : benzene ratio = 1 : 1; temperature 50°; initiator: isopropylbenzene hydroperoxide (0.6 mole %). Chloroprene : hexafluorobutadiene ratio: 1) 2.5 : 7.5; 2) 5.0 : 5.0; 3) 7.5 : 2.5.

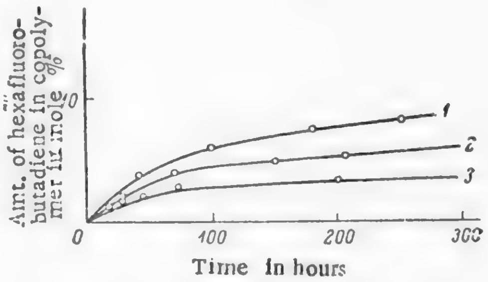


Fig. 6. Change in the composition of the copolymer during joint polymerization as a function of the starting ratio of the monomers. Chloroprene : hexafluorobutadiene ratio: 1) 2.5 : 7.5; 2) 5.0 : 5.0; 3) 7.5 : 2.5.

Influence of the polymerization temperature on the rate of the process and the composition of the copolymers. As can be seen from Fig. 7, the rate of the process depends on the temperature. The rate increases as the temperature is increased. As can be seen from Fig. 8, the temperature exerts a slight influence on the composition of the copolymer formed.

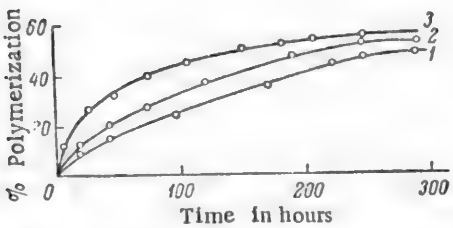


Fig. 7. Relation between the rate of the process and the polymerization temperature. 1) 40°; 2) 50°; 3) 60°.

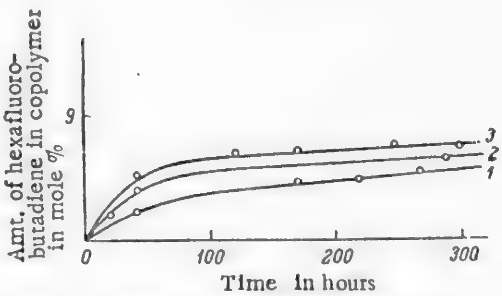


Fig. 8. Change in the composition of the copolymer during the process as a function of the polymerization temperature. 1) 40°; 2) 50°; 3) 60°.

The constants for the joint polymerization of chloroprene and hexafluorobutadiene were calculated using the general integral equation for the composition [2] (Fig. 9), and we also calculated the probability of the amounts of the different types of bonds present in the copolymer and the distribution of the average lengths of the units [3]. In the main, a coupling of the isoprene units with each other is observed when the mixture of copolymers contains a small amount of hexafluorobutadiene. The polymer chains are built from chloroprene units, and the hexafluorobutadiene units couple with each only when the extent of polymerization is high, where the concentration of chloroprene in the mixture of monomers is greatly reduced. In this case, the maximum

probability of the hexafluorobutadiene units coupling is 1.13. The probability of the hexafluorobutadiene units coupling with each other increases as the amount of hexafluorobutadiene in the starting mixture of monomers is increased (5.0 : 5.0 and 2.5 : 7.5), and this becomes greater the greater the amount of hexafluorobutadiene in the starting mixture of monomers and the higher the degree of polymerization. Thus, for example, with a starting monomer ratio of 5.0 : 5.0 and a polymerization extent of 25.2% the probability of the hexafluorobutadiene units coupling with each other is 1.19, while with a starting monomer ratio of 2.5 : 7.5 and a polymerization extent of 23.8% the probability is 2.97; correspondingly, there is a decrease in the probability of the chloroprene units coupling with each other. This serves as evidence that a tendency for the chloroprene and hexafluorobutadiene molecules to alternate is observed as the amount of hexafluorobutadiene in the starting mixture is increased, and also the tendency for the hexafluorobutadiene molecules to couple with each other increases.

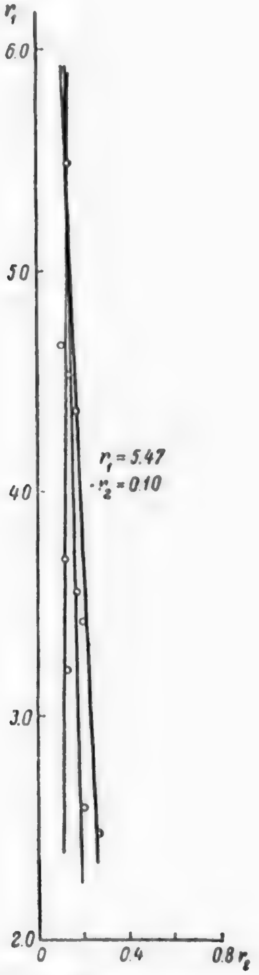


Fig. 9. Determination of the constants for the joint polymerization of chloroprene and hexafluorobutadiene.

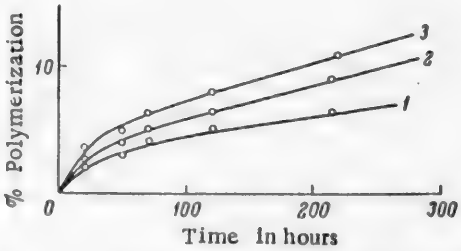


Fig. 10. Dependence of the joint polymerization rate of fluoroprene and hexafluorobutadiene on the starting ratio of the monomers. Monomer: benzene ratio = 1 : 1; initiator = isopropylbenzene hydroperoxide (0.6 mole %); temperature = 50°. Fluoroprene : hexafluorobutadiene ratio: 1) 2.5 : 7.5; 2) 5.0 : 5.0; 3) 7.5 : 2.5.

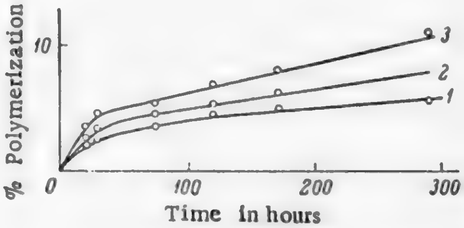


Fig. 11. Dependence of the joint polymerization rate of isoprene and hexafluorobutadiene on the starting ratio of the monomers. Monomer: benzene ratio = 1 : 1; initiator = isopropylbenzene hydroperoxide (0.6 mole %); temperature = 50°. Isoprene : hexafluorobutadiene ratio: 1) 2.5 : 7.5; 2) 5.0 : 5.0; 3) 7.5 : 2.5.

Joint polymerization of fluoroprene with hexafluorobutadiene and of isoprene with hexafluorobutadiene. In order to determine the influence exerted by substituents on the polarity of hydrocarbons and on their activity, we ran some experiments on the joint polymerization of fluoroprene with hexafluorobutadiene and of isoprene with hexafluorobutadiene, using different ratios of the monomers in the starting mixture. In Fig. 10, we have shown the effect of the starting ratio of monomers on the rate of the joint polymerization of fluoroprene and hexafluorobutadiene at a molar ratio of the monomers of 7.5 : 2.5, 5.0 : 5.0 and 2.5: 7.5, respectively. As can be seen from Fig. 10, the rate of the process decreases as

the amount of hexafluorobutadiene in the starting mixture of monomers is increased. In Fig. 11, we have shown a similar relationship for the system isoprene – hexafluorobutadiene at the same starting molar ratios of the monomers. Here also a decrease in the joint polymerization rate is observed as the amount of hexafluorobutadiene in the starting mixture of monomers is increased.

On the basis of the obtained experimental data, we calculated the joint polymerization constants using the general integral equation for the composition (Figs. 12 and 13), and we also calculated the probability of the amounts of the different types of bonds present in the copolymer and the distribution of the average lengths of the monomer units in the copolymer. It was found that

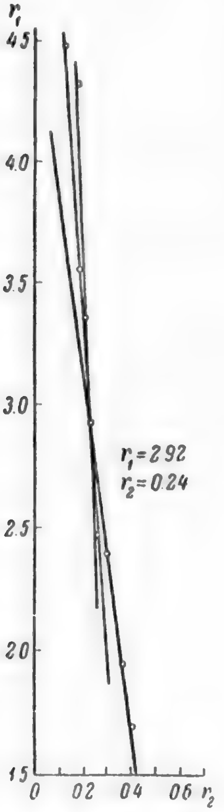


Fig. 12. Determination of the constants for the joint polymerization of fluoroprene and hexafluorobutadiene.

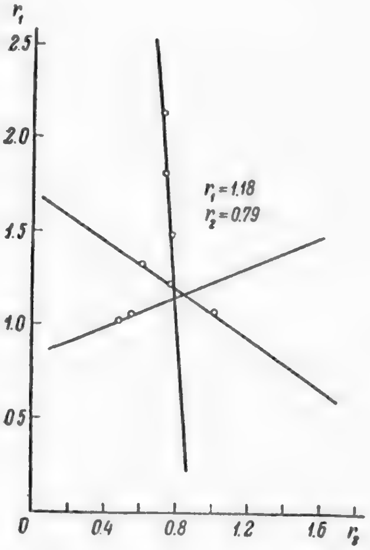


Fig. 13. Determination of the constants for the joint polymerization of isoprene and hexafluorobutadiene.

the probability of the hexafluorobutadiene units coupling with each other increases as the amount of hexafluorobutadiene in the starting mixture of monomers is increased, and the possibility of the monomers alternating with each other also increases. In the joint polymerization of isoprene and hexafluorobutadiene, due to the smaller differences in the reaction rates and the relative reactivity of the monomers, the probability of the hexafluorobutadiene coupling is greater than in the joint polymerization of fluoroprene and hexafluorobutadiene.

Relative activities of monomers and radicals. As is known, in their reactivity the fluorocarbon olefins differ from the olefins. Ethylene and its homologs, although capable of addition reactions, are not very reactive toward a number of nucleophilic polar compounds, which react very easily with the completely fluorinated olefins (addition of ammonia, amines, alcohols, hydrogen sulfide, mercaptans, sodium bisulfite). If ethylene fails to enter into the diene synthesis reaction, then for tetrafluoroethylene a high activity is characteristic in cycloalkylation reactions. All of this indicates that in the fluoroolefins the capacity for dynamic polarization in the reaction with various polar nucleophilic reagents is expressed much more strongly than is the case for the corresponding olefins. This same difference in the properties also appears in the different relative activity shown by olefins and fluorocarbon olefins toward polymerization.

In going from ethylene to diolefins with a conjugated system of double bonds the reactivity of the compounds with respect to both addition and polymerization reactions increases. This increase is due to the presence of a conjugated system of π-electrons, characterized by a high mobility and the ability for the electron density in the molecule to shift with a small loss in energy.

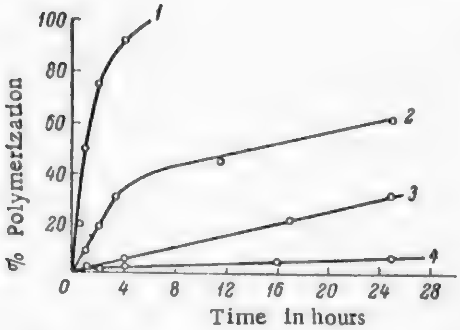


Fig. 14. Polymerization rate of monomers in emulsion. 1) Chloroprene; 2) fluoroprene; 3) isoprene; 4) hexafluorobutadiene.

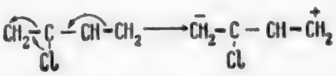
The change in the reactivity when going from fluorocarbon olefins to fluorocarbon diene compounds with a conjugated system of double bonds is not very clear. Based on the values obtained by us for the joint polymerization constants of several monomer systems with a common monomer, namely hexafluorobutadiene, it becomes possible to establish the relative activity of these monomers with respect to the common radical, in which connection it is assumed that the rate constant for the reaction of the hexafluorobutadiene radical with the hexafluorobutadiene monomer is equal to one. The constants for the joint polymerization of the studied monomer systems are expressed by the following values: chloroprene – hexafluorobutadiene, $r_1 = 5.47$, $r_2 = 0.10$; fluoroprene – hexafluorobutadiene, $r_1 = 2.93$, $r_2 = 0.24$; isoprene – hexafluorobutadiene, $r_1 = 1.19$, $r_2 = 0.78$. The constants for the joint polymerization of the following monomer systems are given in the literature: chloroprene – isoprene, $r_1 = 3.65 \pm 0.11$, $r_2 = 0.133 \pm 0.02$ [4]; chloroprene – fluoroprene, $r_1 = 3.70$, $r_2 = 0.22$ [5].

The values of the relative activities of the monomers and radicals are given in the table.

Monomers	Radicals			
	hexafluorobutadiene	isoprene	fluoroprene	chloroprene
Chloroprene	10.0	7.52	4.55	1.00
Fluoroprene	4.16	—	1.00	0.31
Isoprene	1.27	1.0	—	0.28
Hexafluorobutadiene	1.00	0.84	0.34	0.18

As can be seen from the data given in the table, the nature of the substituent in the butadiene molecule exerts a substantial influence on the relative activity of the monomers and the radicals formed. Thus, for example, if discussing the activity of the monomers relative to the hexafluorobutadiene radical, then chloroprene is 10 times more active than hexafluorobutadiene, 8 times more active than isoprene, and 2.4 times more active than fluoroprene. The obtained results are in agreement with the rates of the separate polymerization of the discussed monomers in emulsion (Fig. 14).

The polymerization process was run under the conditions that we had worked out for the polymerization of hexafluorobutadiene. The greater activity of chloroprene when compared with butadiene is due to the fact that introducing a polar chlorine atom into the butadiene molecule upsets the symmetry of the molecule, resulting in a shift of the electron density and a polarization of the molecule. The dipole moment of the molecule is 1.42 D. A shift of the electron density due to conjugation of the π-electrons of the double bond with the unshared electrons of the chlorine atom occurs in the following manner.



As can be seen from the above scheme, a distribution of the electron density occurs in such manner that the No. 1 carbon atom is charged negatively, while the No. 4 atom is charged positively. This is in agreement with the data given in [6] on the manner in which HCl adds to chloroprene, the addition being 1,4. Because of the strong polarity, the molecules show a greater degree of orientation with respect to each other in the 1,4 position and possess a greater activity in the polymerization process than do butadiene molecules. Replacing a hydrogen atom in the butadiene molecule by fluorine also yields a very reactive fluoroprene, which however is somewhat less active than chloroprene. Introducing a fluorine atom into the butadiene molecule also leads to a shift of the electron density and a polarization of the molecule, but the fluorine atom, being more polar than the chlorine atom, is apparently capable of attracting to a greater degree a part of the electron density and in this manner it prevents its free displacement in the molecule, which is reflected in a certain decrease in the activity of fluoroprene when compared with chloroprene. Replacing a hydrogen atom in the butadiene molecule by a methyl group also upsets the symmetry of the molecule, but the CH_3 group is much less capable than either the chlorine or the fluorine atom of exerting an influence on the shift of the electron density. This is manifested in the value of the dipole moment for the isoprene molecule (0.38 D), as a result of which the activity of isoprene in the polymerization reaction is much less than that of either fluoroprene or chloroprene.

When compared with the other monomers discussed here, hexafluorobutadiene shows a quite low activity in both polymerization and joint polymerization reactions. It is hardly possible to explain this as being due to steric hindrance, since tetrafluoroethylene, where all of the hydrogen atoms are also substituted by fluorine, is extremely active in both polymerization and joint polymerization reactions, substantially exceeding ethylene and even butadiene in this respect. Possibly, this low activity of hexafluorobutadiene, when compared with tetrafluoroethylene and butadiene, can be explained by the fact that under the influence of the polar fluorine atoms the electron density in the hexafluorobutadiene molecules exhibits a limited ability to shift, while the presence of conjugation in the system apparently facilitates a greater intramolecular compensation of the polarity and an equalization of the electron density due to the π-electrons, which weakens the conjugation effect considerably.

SUMMARY

1. The conditions for the joint solution polymerization of chloroprene, fluoroprene and isoprene with hexafluorobutadiene were investigated.

2. The constants for the joint polymerization of the investigated monomer systems were calculated.

3. It was established that in their relative activity the monomers can be arranged in the following order: chloroprene > fluoroprene > isoprene > hexafluorobutadiene.

4. From the calculated constants for the joint polymerization of the investigated monomer systems, we derived explanations for the change in the relative activity of the monomers as a function of the nature of the substituent in the butadiene molecule.

LITERATURE CITED

[1] M. O. Korshun and N. É. Gel'man, New Methods of Elemental Microanalysis [In Russian].

[2] S. N. Ushakov, S. P. Mitsengendler, and G. A. Shtraikhman, Uspekhi Khim. 19, 265 (1950).

[3] L. Gindin, A. Abkin, and S. Medvedev, Zhur. Fiz. Khim. 21, 1269 (1947); F. R. Mayo and C. Walling, Chem. Revs. 46, 191 (1950).

[4] R. Simha and L. A. Wall, J. Research National Bureau of Standards 41, 521 (1948).

[5] I. V. Rakityanskii and R. L. Rabinovich, Report of All-Union Scientific Research Institute of Synthetic Rubber [In Russian] (1951).

[6] W. H. Carothers and D. D. Coffman, J. Am. Chem. Soc. 54, 4070 (1932).

INVESTIGATIONS ON THE SYNTHESIS OF PRECURSORS AND FRAGMENTS OF ANTIBIOTICS

1. α-AMINOADIPIC ACID

M. F. Shostakovskii, M. S. Rabinovich, E. V. Preobrazhenskaya, and G. N. Zykova

All-Union Scientific Research Institute of Antibiotics

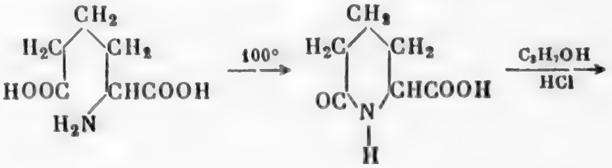
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 67-71, January, 1960

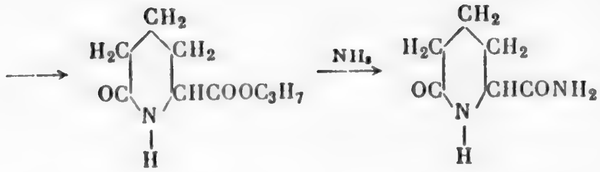
Original article submitted December 29, 1958

In studying the structure of cephalosporin N, showing a high activity against various pathogenic bacteria, it was established that this antibiotic is a penicillin, the side chain of which contains D-α-aminoadipic acid [1]. In order to determine if it is possible to use the latter as a precursor in the biosynthesis of cephalosporin N we undertook the task of synthesizing racemic α-aminoadipic acid, with subsequent cleavage of the latter into the optically active isomers.

Most of the known methods for the synthesis of α-aminoadipic acid reduce mainly to two routes: preparation of the α-halo-substituted ester of adipic acid [2-4], with subsequent replacement of the halogen by the amino group [5], and condensation of the corresponding dihaloalkyls, or halonitriles with malonic, or substituted malonic ester, and subsequent decarboxylation and hydrolysis [6]. The success of the first route is entirely dependent on the purity of the α-halo-substituted ester, which in turn is linked with its method of preparation. Of the methods checked by us for the synthesis of diethyl α-bromoadipate the method described in [2] proved to be the best. According to this method, the monoethyl ester of adipic acid is used as the starting material, which assures obtaining the pure monobromo ester later. The use of adipoyl dichloride [4] as the starting material leads to obtaining low yields in the subsequent steps of amination and hydrolysis.

When we tried to aminate diethyl α-bromoadipate by heating the latter with alcoholic ammonia solution we isolated, instead of the expected diamide of α-aminoadipic acid with the composition $C_6H_{13}O_2N_3$, a compound that crystallized readily from alcohol and had the composition $C_6H_{10}O_2N_2$, which when hydrolyzed by heating with hydrochloric acid was converted to α-aminoadipic acid hydrochloride. The elemental composition permits assuming the formation of the imide of α-aminoadipic acid. However, the ability of α-aminoadipic acid to cyclize readily, leading to the formation of 2-oxopiperidine-6-carboxylic acid [7], makes it possible to obtain the amide of this heterocyclic acid in the present case. This we were able to show by direct comparison with the amide synthesized in the following manner:

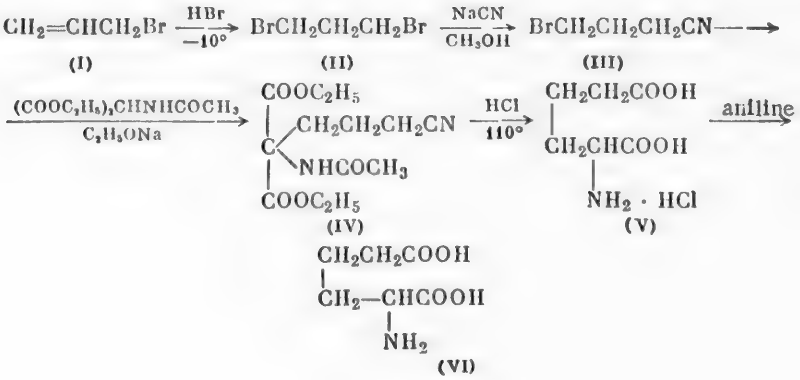




The great ease with which α-aminoadipic acid cyclizes was also demonstrated when the latter is recrystallized from water: here not more than 50% of the acid taken for recrystallization is recovered as such. In all of its properties and elemental composition, the substance isolated from the mother liquor corresponds to 2-oxopiperidine-6-carboxylic acid. To purify α-aminoadipic acid, we were able to obtain good results by using the technique of reprecipitation: a solution of the acid in 1 N NaOH, purified by shaking with activated carbon, was acidified to pH 3-3.5 to give the acid as a colorless precipitate. The yield of acid exceeds 90%.

When the acid was heated with anhydrous isopropyl alcohol, containing HCl, instead of the expected diisopropyl ester of α-aminoadipic acid, $C_{12}H_{23}O_4N$, we obtained a substance with the composition $C_9H_{15}O_3N$, which indicates that it is possible to form the isopropyl ester of 2-oxopiperidine-6-carboxylic acid. The validity of our assumption was shown by the counter synthesis of this ester, starting with the oxopiperidinecarboxylic acid.

In a search for other methods of obtaining α-aminoadipic acid, we synthesized it in the following manner:



EXPERIMENTAL

DL-α-Aminoadipic acid. a) To a cooled solution of freshly prepared sodium alcoholate (1.1 g Na, 30 ml of anhydrous alcohol) was added 10.7 g of acetamidomalonic ester; the mixture was heated at 85-90° for 20 minutes, after which 7.3 g of γ-bromobutyronitrile* was added from a dropping funnel. The heating and stirring were continued for 7 hours (until the reaction was no longer alkaline to phenolphthalein). The residue after distilling off the alcohol was dissolved in 30 ml of water and then extracted with ether. The ether solution was then dried, followed by evaporation of the ether, and the oily residue of condensation product (11.2 g) was then

* Obtained by the method described for the synthesis of trimethylene cyanide [8], but reducing the amount of sodium cyanide used to 0.5 mole per mole of trimethylene bromide; b. p. 95-105° at 20 mm [9]. Yield 40% (based on sodium cyanide).

To obtain trimethylene bromide we passed gaseous HBr into a receiver containing allyl bromide (175 g) [10]. The addition was made at −10 to −15° until the weight of the reaction mass remained constant. The amount of HBr absorbed in 5 hours was 120 g. The reaction product was washed with water, $NaHCO_3$ solution, again with water, and then dried over $CaCl_2$; b. p. 162-166° [9]. The yield of trimethylene bromide was 241.4 g (83.5%).

subjected to decarboxylation and hydrolysis by refluxing with 25 ml of concentrated HCl for 11-12 hours. The acid solution was evaporated in vacuo, and the dry residue was dissolved in water (7-8 ml). The addition of excess aniline, followed by cooling, caused the α-aminoadipic acid to crystallize. Yield 3.5 g (44%, based on γ-bromobutyronitrile).

b) Fifty grams of diethyl α-bromoadipate [2], obtained from monoethyl adipate [11], was dissolved in 1300 ml of anhydrous ethyl alcohol, saturated with gaseous ammonia (about 10%), and the solution charged into an autoclave, where it was heated for 12 hours at 100-110° (pressure 7 atm). Removal of the alcohol by distillation left a yellow crystalline mass, which proved to be the amide of 2-oxopiperidine-6-carboxylic acid. After recrystallization from alcohol (1:10), m. p. 168-169°.

Found %: C 50.70, 50.76; H 7.32, 7.15; N 19.89, 20.07. $C_6H_{10}O_2N_2$. Calculated %: C 50.7; H 7.04; N 19.71.

The obtained substance was heated with concentrated HCl (150 ml) on the boiling water bath for 4 hours, after which it was evaporated in vacuo to dryness. The residue was dissolved in water (50 ml). The addition of excess aniline caused the α-aminoadipic acid to crystallize. Yield 23 g (82%, based on diethyl α-bromoadipate).

The technical α-aminoadipic acid (23 g) was purified by dissolving in 1 N NaOH (150 ml) and then treating the weakly alkaline solution (pH 8.0) with activated carbon. Acidification of the colorless filtrate to pH 3-3.5 (13 ml of concentrated HCl) gave 20.8 g (94%) of crystalline α-aminoadipic acid, m. p. 173-174° (decomp.).

Found %: C 44.41, 44.53; H 7.07, 7.10; N 8.80, 8.90. $C_6H_{11}O_4N$. Calculated %: C 44.72; H 6.83; N 8.69.

2-Oxopiperidine-6-carboxylic acid. α-Aminoadipic acid (5 g) was recrystallized from water (100 ml). We recovered 2.4 g of crystalline α-aminoadipic acid with m. p. 173-174° (decomp.). Evaporation of the mother liquor to incipient crystallization gave 2 g of substance, which was recrystallized from 7 ml of water. The obtained 2-oxopiperidine-6-carboxylic acid had m. p. 178-179° [7] (without decomp.). The mixed melting point with α-aminoadipic acid was 169-170° (decomp.).

Found %: C 50.45, 50.27; H 6.21, 6.14; N 10.02, 9.68. $C_6H_9O_3N$. Calculated %: C 50.34; H 6.29; N 9.79.

Isopropyl ester of 2-oxopiperidine-6-carboxylic acid. a) A mixture of 9.6 g of α-aminoadipic acid and 45 ml of anhydrous isopropyl alcohol, containing 16% of gaseous HCl, was heated at 105-110° for 3.5 hours. After evaporation of the alcohol, the residue was dissolved in 10 ml of water; then with cooling in ice, in the presence of ether, 10% $NaHCO_3$ solution was added until the reaction was no longer acid. The ether extract was dried, evaporated, and the residue was distilled at 165-166° (5 mm). The substance crystallized during the distillation. After recrystallization (2.3 g) from petroleum ether (1:10) and ethyl ether (1:5), m. p. 65.5-66.5°.

Found %: C 58.57, 58.33; H 8.32, 8.25; N 7.55, 7.77. $C_9H_{15}O_3N$. Calculated %: C 58.37; H 8.10; N 7.56.

b) 2-Oxopiperidine-6-carboxylic acid (obtained from α-aminoadipic acid) was esterified under the conditions described for the esterification of α-aminoadipic acid. After distilling off the ether, the residue crystallized. After recrystallization from ether, m. p. 64-65°. The mixed melting point with the esterification product of α-aminoadipic acid was not depressed.

Found %: C 58.20, 58.27; H 8.20, 8.21; N 7.71, 7.36. $C_9H_{15}O_3N$. Calculated %: C 58.37; H 8.10; N 7.56.

The mixing of isopropyl 2-oxopiperidine-6-carboxylate (1.3 g) with 6% alcoholic ammonia solution (6 ml), followed by heating in a sealed tube at 100° for 10 hours, gave a crystalline substance (0.7 g), which after recrystallization from anhydrous alcohol (1:10) melted at 168-169°. The mixed melting point with the amination product of diethyl α-bromoadipate was not depressed.

Found %: C 50.78, 50.51; H 7.28, 7.08; N 19.34, 19.68. $C_6H_{10}O_2N_2$. Calculated %: C 50.7; H 7.04; N 19.71.

We wish to thank A. S. Khokhlov and E. M. Kleiner for supplying the α-aminoadipic acid samples and F. M. Meller for running all of the elemental analyses.

SUMMARY

1. DL-α-Aminoadipic acid was synthesized by two routes: a) condensation of γ-bromobutyronitrile with N-acetamidomalonic ester, followed by hydrolysis and decarboxylation, and b) amination of diethyl α-bromoadipate with subsequent hydrolysis.

2. It was found that the heating of diethyl α-bromoadipate with alcoholic ammonia solution yields the amide of 2-oxopiperidine-6-carboxylic acid.

3. It was established that the ordinary recrystallization of α-aminoadipic acid from water results in about 50% of it converting to 2-oxopiperidine-6-carboxylic acid.

4. It was shown that the esterification of α-aminoadipic acid by heating with isopropyl alcohol in the presence of HCl yields the isopropyl ester of 2-oxopiperidine-6-carboxylic acid.

LITERATURE CITED

[1] E. P. Abraham and G. G. F. Newton, Khim. Nauka i Prom. 1, 394 (1956).

[2] E. Schwenk and D. Papa, J. Am. Chem. Soc. 70, 3626 (1948).

[3] Ng. Ph. Buu-Hoi and P. Demerseman, J. Org. Chem. 18, 649 (1953).

[4] W. Treibs and G. Leichssenring, Ber. 84, 52 (1951).

[5] T. P. Waalkes, W. S. Fones, and J. White, J. Am. Chem. Soc. 72, 5760 (1950).

[6] S. P. L. Sorensen, Compt. rend. trav. lab. Carlsberg, Ser. Chim. 6, 1 (1903); J. von Braun and F. Meyer, Ber. 74B, 19 (1941); H. Borsook, C. L. Deasy, A. J. Haagen-Smit, G. Keighley, and P. H. Lowy, J. Biol Chem 176, 1386 (1948); M. Rothstein and C. J. Claus, J. Am. Chem. Soc. 75, 2981 (1953).

[7] W. Dieckmann, Ber. 38, 1654 (1905).

[8] Organic Syntheses, Coll. Vol. I, p. 536 (1949).

[9] C. G. Derick and R. W. Hess, J. Am. Chem. Soc. 40, 547 (1918).

[10] M. F. Shostakovskii, Zhur. Priklad. Khim. 9, 681 (1936).

[11] G. B. Brown, B. R. Baker, S. Bernstein, and S. Safir, J. Org. Chem. 12, 162 (1947).

INVESTIGATIONS ON THE SYNTHESIS OF PRECURSORS AND FRAGMENTS OF ANTIBIOTICS

II. RESOLUTION OF DL-α-AMINOADIPIC ACID INTO OPTICALLY ACTIVE FORMS

M. S. Rabinovich, M. F. Shostakovskii, and
E. V. Preobrazhenskaya*

All-Union Scientific Research Institute of Antibiotics

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 71-75, January, 1960
Original article submitted December 29, 1958

Two methods are described in the literature for the resolution of racemic α-aminoadipic acid into the optical antipodes. L-α-Aminoadipic acid, $[\alpha]^{25}D + 33.9°$ (c 5.49; 6 N HCl), was obtained by treating carbobenzoxy-DL-α-aminoadipic acid with aniline and papain, followed by hydrolysis of the anilide and removal of the carbobenzoxy group from the isolated L-form [1] (no mention of the D-form is made in the paper), while the second method given in the literature describes the resolution of DL-α-aminoadipic acid by the enzymatic hydrolysis of N-chloroacetyl-DL-α-aminoadipic acid using acylases [2]. The N-chloroacetyl group of the L-form is hydrolyzed at pH 7.0, whereas the D-form remains unchanged. To isolate the D-α-aminoadipic acid requires subsequent hydrolysis with boiling 2 N HCl. The indices for the angle of rotation differ from those given in [1]: for the L-form, $[\alpha]^{25}D + 25°$ (c 2; 5 N HCl), and for the D-form, $[\alpha]^{25}D - 25°$ (c 2; 6 N HCl).

To separate DL-α-aminoadipic acid into the optical antipodes we used the method of resolution through the diastereomers, which, as is known, was first worked out by Pasteur specifically for compounds of acid character [3]. In most cases alkaloids are used as the asymmetric reagent of basic character. However, the free amino acids, being inner salts, are incapable of forming stable salts with such fairly weak bases as the alkaloids. For this reason, the method of resolution through the acyl derivatives, described in detail in the classic studies of Fischer [4], is usually used even today for the separation of amino acids [5], and it was the method adopted by us to obtain the optically active forms of α-aminoadipic acid. We first synthesized the N-benzoyl derivative, from which we were able to obtain the neutral crystalline salt with brucine. After 2-3 recrystallizations of the salt, we isolated N-benzoyl-L-α-aminoadipic acid, $[\alpha]_D$ + 16°, from it. The mother liquors yielded a noncrystalline glassy salt, from which we isolated N-benzoyl-D-α-aminoadipic acid, $[\alpha]_D - 16°$. After hydrolysis of the benzoyl group by heating with 10% HCl we obtained the optically active forms of α-aminoadipic acid, $[\alpha]_D$ + + 25.5 and − 25.0°.

However, the use of brucine for resolution into the optically active forms is associated with a number of difficulties, including the high toxicity and the comparatively difficult availability of this alkaloid. For this reason the problem of using synthetic optically active bases assumes great interest, especially since both antipodes, as a rule, are readily available. This makes it easy to obtain both optical forms of the substance being resolved

* We wish to thank M. A. Guberniev for the interest displayed in our work.

in pure form. α-Phenethylamine [6] and 2-amino-1-phenylpropane (benzedrine) [7] are used quite extensively in the resolution of acids. We set ourselves the task of determining if it is possible to resolve DL-α-aminoadipic acid using L-threo-1-p-nitrophenyl-2-amino-1,3-propanediol. In recent years a number of papers have appeared in the literature describing the resolution of DL-acetyltryptophan [8] and DL-threo-β-phenylserine [5] using the L-form of this amine.

The same as when working with brucine, we used N-benzoyl-DL-α-aminoadipic acid to obtain the salts. By using 2 moles of base per mole of acid we were able to obtain the salt with both the L- and the D-isomer of the amine, both crystallizing well from aqueous acetone. Two recrystallizations proved to be sufficient to give a salt with a constant angle of rotation (approximately 9.0°). The crystalline salt of the D-N-benzoyl derivative separates when the L-form of the amine is used, while using the D-form of the amine yields the crystalline salt of L-N-benzoylaminoadipic acid. The N-benzoyl derivatives from the crystalline salts, as well as the optically active forms of α-aminoadipic acid isolated from the former, show the same angles of rotation as were obtained using brucine for the resolution.

The amorphous glassy salts isolated from the evaporated aqueous-acetone mother liquors had a rotation of ± 18-20°, while the N-benzoyl derivatives obtained from them had a rotation of ± 8-11°. For further resolution the N-benzoyl derivatives were again converted to the salts by reaction with the amine of opposite sign of rotation, and the salts after one recrystallization showed a constant angle of rotation (approximately ± 9.0°). As a result, we were able to find a convenient method for the resolution of DL-α-aminoadipic acid using a very readily available synthetic amine, being an intermediate in the commercial synthesis of levomycetin.

An interesting fact in the resolution of racemic α-aminoadipic acid using the microorganism Penicillium chrysogenum was established in a joint study with T. P. Verkhovtseva (Division of Physiology of the All-Union Scientific Research Institute of Antibiotics). Here, it was found that the fungus utilizes only the L-form of α-aminoadipic acid in its metabolism. In 5-6 days after adding the racemate to the mold culture medium we isolated the D-form of α-aminoadipic acid, $[\alpha]_D - 25.9°$, from the filtrate.

A study of the resolution of other racemic amino acids using the optically active forms of D-threo-1-p-nitrophenyl-2-amino-1,3-propanediol is being continued.

EXPERIMENTAL

N-Benzoyl-DL-α-aminoadipic acid. Sixteen grams of DL-α-aminoadipic acid was added to a suspension of 90 g of sodium bicarbonate in 300 ml of water. When the brisk evolution of carbon dioxide had ceased, 42 g of benzoyl chloride was added gradually in 1.5 hours with vigorous stirring. The stirring was continued for another 4 hours, after which the undissolved excess sodium bicarbonate was filtered, and the filtrate was acidified with concentrated HCl to pH 2.0. The mixture of benzoic and N-benzoyl-α-aminoadipic acids was suction-filtered, dried, and extracted with ether in an extractor. The insoluble N-benzoyl-α-aminoadipic acid (19.5 g) was recrystallized from water (1:10). Yield 18 g (68%), m. p. 183-184°.

Found %: C 58.66, 58.50; H 5.81, 5.87; N 5.56, 5.31. $C_{13}H_{15}O_5N$. Calculated %: C 58.8; H 5.6; N 5.28.

Salt of N-benzoyl-DL-α-aminoadipic acid with brucine. A mixture of 16.8 g of N-benzoyl-DL-α-aminoadipic acid and 50.4 g of brucine was dissolved with heating in 300 ml acetone + 30 ml water. After cooling, the deposited crystalline salt was suction-filtered and dried at 50-60° to give 48.7 g of salt A_1. Recrystallization from 200 ml acetone + 20 ml water gave 39.6 g of salt A_2. A second recrystallization from 160 ml of acetone and 16 ml of water gave 34.4 g of salt A_3; further recrystallization from 140 ml of acetone and 14 ml of water gave 31.4 g of salt A_4.

Found %: C 64.10, 64.12; H 6.73, 6.67; N 6.34, 6.23. $C_{59}H_{67}O_{13}N_5 \cdot 3H_2O$. Calculated %: C 63.95; H 6.59; N 6.32.

N-Benzoyl-L-α-aminoadipic acid. Salt A_4 (31.4 g) was dissolved with heating in 160 ml of water. The cooled solution was then treated with 1 N NaOH solution to pH~9.0 . The deposited brucine was suction-filtered, and the filtrate was shaken with chloroform, after which it was acidified with 10% HCl to pH approximately 2.0, where 6.7 g of N-benzoyl-L-α-aminoadipic acid crystallized out, m. p. 179-180°, $[\alpha]_D + 17.3°$ (c 4.1; 1 N NaOH).

N-Benzoyl-D-α-aminoadipic acid. The aqueous-acetone mother liquor from salt A_1 was evaporated in vacuo; the residue was 21.3 g of semicrystalline salt B_1, which was dissolved by refluxing with 85 ml of acetone and 9 ml of water. Cooling of the solution gave about 1 g of crystalline salt A_1; evaporation of the filtrate gave 19.3 g of glassy salt B_2. Decomposition of salt B_2 with alkali, followed by removal of the brucine, and then acidification of the filtrate led to the isolation of 3.65 g of N-benzoyl-D-α-aminoadipic acid with m. p. 178-179°, $[\alpha]_D$ − 16.0° (c 3.3; 1 N NaOH).

L- and D-α-Aminoadipic acids. The obtained N-benzoyl derivatives, $[\alpha]_D$ + 17.3° and $[\alpha]_D$ − 16°, were hydrolyzed by heating with 10% HCl (1 : 15) for 15 hours at 110-115°. The deposited benzoic acid was removed by extraction with ether, and the acid solution was then evaporated in vacuo. The optically active α-aminoadipic acids were then isolated by adding excess aniline to water solutions of the obtained hydrochlorides, after which they were purified by dissolving in 1 N NaOH, treating the solution with activated carbon, and precipitation with 10% HCl at pH 3.5-4. From 6.6 g of N-benzoyl-L-α-aminoadipic acid we obtained 2.8 g of L-α-aminoadipic acid with m. p. 184-185°; $[\alpha]_D$ + 25.5° (c 1.3; 6 N HCl). From 3.6 g of the D-N-benzoyl derivative we obtained 1.8 g of D-α-aminoadipic acid, m. p. 183-184°, and $[\alpha]_D$ − 25° (c 1.3; 6 N HCl).

Salt of N-benzoyl-DL-α-aminoadipic acid with L-threo-1-p-nitrophenyl-2-amino-1,3-propanediol. A mixture of 13.3 g of N-benzoyl-DL-α-aminoadipic acid and 22.3 g of L-threo-1-p-nitrophenyl-2-aminopropanediol was dissolved with heating in 100 ml of acetone and 10 ml of water. Cooling of the solution gave 16.7 g of crystalline salt A_1L, $[\alpha]_D$ + 11.4° (c 3.2; H_2O), which was recrystallized from 150 ml of acetone and 15 ml of water. We obtained 11.6 g of salt A_2L, $[\alpha]_D$ + 9.0° (c 3.2; H_2O). Recrystallization from 105 ml of acetone and 11 ml of water gave 8.8 g of salt A_3L, $[\alpha]_D$ + 9.3° (c 3.2; H_2O).

Found %: C 52.81, 52.87; H 6.00, 6.05; N 10.1, 9.83. $C_{31}H_{39}O_{13}N_5 \cdot H_2O$. Calculated %: C 52.67; H 5.8; N 9.9.

N-Benzoyl-D-α-aminoadipic acid. Salt A_3L (8.8 g) was dissolved with heating in 90 ml of water, after which the solution was made alkaline with 25% NH_4OH to pH approximately 9.0, and the deposited amine was separated. Acidification of the filtrate with 10% HCl to pH 2.0 gave 2.8 g of crystalline N-benzoyl-D-α-aminoadipic acid, m. p. 179-180°, and $[\alpha]_D$ − 18.6° (c 4.2; 1 N NaOH).

N-Benzoyl-L-α-aminoadipic acid. The aqueous-acetone mother liquor from the separation of salt A_1L was evaporated in vacuo. We obtained 19 g of glassy salt B_1D, $[\alpha]_D$ + 18.9° (c 5.2; H_2O), from which 6.9 g of the N-benzoyl derivative, $[\alpha]_D$ + 8.9° (c 3.25; 1 N NaOH), was isolated. For further separation, the latter was converted to the salt with D-threo-1-nitrophenyl-2-aminopropanediol; here we isolated 10.8 g of salt A_1D, $[\alpha]_D$ − 11.5° (c 3.2; H_2O). A second recrystallization from 100 ml of acetone and 10 ml of water gave 7 g of salt A_2D, $[\alpha]_D$ − 9.5° (c 3.2; H_2O), from which we isolated 2.4 g of N-benzoyl-L-α-aminoadipic acid, m. p. 177-178° and $[\alpha]_D$ + 17.2° (c 4.2; 1 N NaOH).

Salt of N-benzoyl-DL-α-aminoadipic acid with D-threo-1-p-nitrophenyl-2-amino-1,3-propanediol. A mixture of 26.5 g of the DL-N-benzoyl derivative and 42.4 g of the D-isomer of the base was processed under the conditions described for obtaining the salt with the L-isomer. We isolated 36.9 g of salt A_1D, $[\alpha]_D$ − 13°. As the result of successive recrystallizations, we obtained in respective order 20.8 g of salt A_2D, $[\alpha]_D$ − 9.8°, and 14.2 g of salt A_3D, $[\alpha]_D$ − 9.5°. From the latter we isolated 4.6 g of N-benzoyl-L-α-aminoadipic acid, $[\alpha]_D$ + 16.9°. From the aqueous-acetone mother liquor from salt A_1D we isolated 32.1 g of salt B_1L $[\alpha]_D$ − − 20.19°, from which we obtained 11.5 g of the N-benzoyl derivative, $[\alpha]_D$ − 11.2°. Further separation of the latter through the salt with L-threo-1-p-nitrophenyl-2-aminopropanediol gave 4.0 g of N-benzoyl-D-α-aminoadipic acid, $[\alpha]_D$ − 17.5°. Hydrolysis of the obtained optically active N-benzoyl derivatives gave: D-α-aminoadipic acid, $[\alpha]_D$ − 24.5°, and L-α-aminoadipic acid, $[\alpha]_D$ + 25.5°.

Resolution of DL-α-aminoadipic acid with the mold Penicillium chrysogenum. The mold mycelium, washed free of culture liquid, was added to a water solution containing Na and K phosphates and glucose, and then the DL-α-aminoadipic acid was added (3% on the solution volume). After 6 days of culturing, the mycelium was separated and the filtrate (40 ml) was acidified with 6 N HCl to pH approximately 2.0, followed by evaporation in vacuo to dryness. The residue was dissolved in 8-10 ml of water, aniline was added, and the obtained precipitate of α-aminoadipic acid was separated and dissolved in several milliliters of 1 N NaOH. The alkaline solution was washed with ether to remove traces of aniline, and then it was acidified carefully with 15% HCl to pH 3.5-4. We obtained 0.3 g of D-α-aminoadipic acid, $[\alpha]_D$ − 25.9° (c 1.5; 6 N HCl).

SUMMARY

1. The previously unknown N-benzoyl-DL-α-aminoadipic acid was synthesized.

2. The resolution of N-benzoyl-DL-α-aminoadipic acid into the optically active forms was accomplished by preparing the crystalline salts with: a) brucine, b) L-threo-1-p-nitrophenyl-2-aminopropanediol, and c) DL-threo-1-p-nitrophenyl-2-aminopropanediol.

3. Hydrolysis of the optically active forms of N-benzoyl-α-aminoadipic acid gave the L- and D-α-aminoadipic acids.

4. It was established that when the fungus Penicillium chrysogenum is cultured in the presence of DL-α-aminoadipic acid, the latter suffers resolution into the optically active forms.

LITERATURE CITED

[1] H. Borsook, C. L. Deasy, A. J. Haagen-Smit, et al., J. Biol. Chem. 176, 1386 (1948).

[2] J. P. Greenstein, S. M. Birnbaum, and M. Clyde Otey, J. Am. Chem. Soc. 75, 1994 (1953).

[3] L. Pasteur, Ann. Chem. Phys. 38, 438 (1853).

[4] E. Fischer, Ber. 32, 2451 (1899); E. Fischer and R. von Gravenitz, Ann. 406, 5 (1914).

[5] C. G. Alberti, B. Camerino, A. Vercellone, and S. Redaelli, Gazz. chim. ital. 83, 930 (1953); Referat. Zhur. Khim. (1955), 9600.

[6] R. Adams and L. O. Binder, J. Am. Chem. Soc. 63, 2773 (1941); S. Wawzonek and J. P. Henry, J. Org. Chem. 18, 1461 (1953).

[7] M. Matell, Arkiv Kemi 8, 79 (1955).

[8] L. Velluz, G. Amiard, and R. Heymes, Bull. soc. chim. France (1953), 904; Referat. Zhur. Khim. (1954), 32464.

REACTION OF BIACETYLENE WITH AMINO ALCOHOLS AND AMINES

I. SYNTHESIS AND TRANSFORMATIONS OF 1-(2-DIETHYLAMINOETHOXY)-1-BUTEN-3-YNE

M. F. Shostakovskii, I. A. Chekulaeva, and L. V. Kondrat'eva

Institute of Organic Chemistry, Academy of Sciences of the USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 75-81, January, 1960

Original article submitted October 13, 1958

The number of papers in the literature devoted to a study of the properties of biacetylene are comparatively few. In the main, the reaction of biacetylene with organic oxo compounds and mercaptans in the presence of alkaline agents is described [1-10]. The data on the reaction of biacetylene with amino alcohols is limited only to the statements of Reppe [10] on the reaction of biacetylene with methylolamines, which proceeds at 60-70° with the liberation of water and the formation of mono- and disubstituted products.

$$HC{\equiv}C{-}C{\equiv}CH + HOCH_2NR_2 \longrightarrow R_2NCH_2C{\equiv}C{-}C{\equiv}CH \xrightarrow{R_2NCH_2OH} R_2NCH_2C{\equiv}C{-}C{\equiv}CCH_2NR_2$$

Because of the high reactivity of biacetylene and the presence of several functional groups in amino alcohols it can be assumed that they will react with each other in several directions, both at the hydroxyl and at the amino group. This lends additional interest to studying the given reaction and expands the synthesis possibilities.

First of all it was in order to study the reaction of biacetylene with those amino alcohols not having hydrogens on the nitrogen atom. The reason for this was to exclude the possibility of biacetylene reacting at the amino group and also to ascertain the influence exerted by the latter on the addition of the amino alcohol to biacetylene and on the properties of the ethynylvinyl ethers that are formed here. This investigation was made using 2-diethylaminoethanol, and the principal results of this investigation were reported earlier [11].

In this paper we give a detailed description of the results along with some additions. It was shown that biacetylene reacts with 2-diethylaminoethanol under milder conditions than do the unsubstituted alkyl alcohols [1], and to be specific, at room temperature without a catalyst, in which connection the reaction goes with the formation of only 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) in good yield (80-90%).

$$HC{\equiv}C{-}C{\equiv}CH + HOCH_2CH_2N(C_2H_5)_2 \longrightarrow HC{\equiv}C{-}CH{=}CHOCH_2CH_2N(C_2H_5)_2 \qquad (I)$$

Based on earlier papers [1-10], it could be expected that, together with the ethynylvinyl ether (I), the addition product of two molecules of the amino alcohol to one molecule of biacetylene should also be formed. However, this was not observed under the given conditions.

The following transformations of the ethynylvinyl ether (I) were examined: hydrolysis, and the addition of alcohols and mercaptans. It was proposed to compare the behavior of 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) and the unsubstituted 1-alkoxy-1-buten-3-ynes in these reactions.

The hydrolysis of 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) with 10% sulfuric acid solution gave 1,3,5-triacetyl benzene (80% yield). The reaction of (I) with aliphatic alcohols (2-diethylaminoethanol and butanol) required more drastic conditions when compared with the unsubstituted 1-alkoxy-1-buten-3-ynes (in the presence of potassium alcoholate as the catalyst, at a higher temperature, or by boiling in vacuo). Together with the formation of acetals of 1-butyn-4-al, this reaction also gave the addition products of one molecule of the alcohol to a molecule of the ethynylvinyl ether, having a diene and an allene structure. The nature of the adding alcohol determined both the reaction conditions and the ratio of the reaction products. Thus, for example, the predominant formation of 1,3-di(2-diethylaminoethoxy)-1,3-butadiene (II) (55-60% yield) was observed in the case of 2-diethylaminoethanol.

$$\underset{\displaystyle OCH_2CH_2N(C_2H_5)_2}{CH_2{=}\overset{}{C}}{-}CH{=}CHOCH_2CH_2N(C_2H_5)_2 \qquad \text{(II)}$$

$$(C_2H_5)_2NCH_2CH_2OCH{=}CH{-}CH{=}CHOCH_2CH_2N(C_2H_5)_2 \qquad \text{(IIa)}$$

The hydrolysis of (II) can lend some support to the alkoxy groups being in the 1,3-position in this product, since 1,3,5-triacetylbenzene (25% yield) is formed here. However, the possibility of the isolated compound also containing 1,4-di(2-diethylaminoethoxy)-1,3-butadiene (IIa) is not excluded.

The reaction of (I) with butanol led to the predominant formation (50-60%) of the acetal of 1-butyn-4-al (III), containing the product with the allene structure as impurity. The yield of 1-butoxy-4-(2-diethylamino-ethoxy)-1,3-butadiene (IV) was only 10-25%.

$$CH_3C{\equiv}CCH\begin{cases}OC_4H_9\\ OCH_2CH_2N(C_2H_5)_2\end{cases} \quad \text{(III)}$$

$$H_9C_4OCH{=}CH{-}CH{=}CHOCH_2CH_2N(C_2H_5)_2 \quad \text{(IV)}$$

(or a 1,3-arrangement of the alkoxy groups)

It is obvious that in the reaction of ethynylvinyl ether (I) with alcohols there occurs, together with isomerization leading to a migration of the triple bond, also an acetylene-allene-diene isomerization of the reaction products, which leads to the formation of dialkoxy-1,3-butadienes.

$$HC{\equiv}C{-}CH{=}CHOCH_2CH_2N(C_2H_5)_2 + HOR \rightarrow HC{\equiv}C{-}CH_2CH\begin{cases}OR\\ OCH_2CH_2N(C_2H_5)_2\end{cases} \rightarrow$$

$$\rightarrow CH_2{=}C{=}CH{-}CH\begin{cases}OR\\ OCH_2CH_2N(C_2H_5)_2\end{cases} \rightarrow \begin{cases}CH_3C{\equiv}C{-}CH(OR)OCH_2CH_2N(C_2H_5)_2\\ CH_2{=}C(OR)CH{=}CHOCH_2CH_2N(C_2H_5)_2\end{cases}$$

$R{=}C_4H_9$ и $CH_2CH_2N(C_2H_5)_2$.

Also not excluded is the possibility of the alcohols adding to the ethynylvinyl ether under the given conditions simultaneously at the triple and double bonds, which also leads to obtaining a mixture of products of variable structure.

If the time of reacting 1-(2-diethylaminoethoxy)-1-buten-3-yne with 2-diethylaminoethanol is increased substantially (from 6 to 22 hours), then the isolated product represents the addition product of two molecules of the amino alcohol to one molecule of the ethynylvinyl ether (yield 80%), which, according to the spectral analysis data, has the structure of either (V) or (Va).

$$\underset{\displaystyle OCH_2CH_2N(C_2H_5)_2}{CH_2{=}C}{-}CH_2CH[OCH_2CH_2N(C_2H_5)_2]_2 \quad \text{(V)}$$

$$\underset{\displaystyle OCH_2CH_2N(C_2H_5)_2}{CH_3C}{=}CH{-}CH[OCH_2CH_2N(C_2H_5)_2]_2 \quad \text{(Va)}$$

Ethyl mercaptan adds to (I) with the formation, the same as in the case of unsubstituted 1-alkoxy-1-buten-3-ynes, of ethylmercapto-(2-diethylaminoethoxy)-1,3-butadiene (VI) or (VIa) (yield 60-70%), but under milder conditions (simply by heating to 70°).

$$C_2H_5SCH{=}CH{-}CH{=}CHOCH_2CH_2N(C_2H_5)_2 \quad \text{(VI)}$$

$$CH_2{=}\underset{\displaystyle SC_2H_5}{\underset{|}{C}}{-}CH{=}CHOCH_2CH_2N(C_2H_5)_2 \quad \text{(VIa)}$$

Next we made an attempt to obtain the ethylmercapto-(2-diethylaminoethoxy)-1,3-butadiene (VI) and the butoxy derivatives of the ethynylvinyl ether (III and IV) by the counter synthesis from 1-ethylmercapto-1-buten-3-yne ($C_2H_5SCH{=}CH{-}C{\equiv}CH$) and 1-butoxy-1-buten-3-yne ($C_4H_9OCH{=}CH{-}C{\equiv}CH$), respectively. However, we were unable to obtain the addition of 2-diethylaminoethanol to 1-ethylmercapto-1-buten-3-yne by boiling in vacuo in the presence of potassium alcoholate as catalyst. The reaction of 2-diethylaminoethanol with 1-buto[illegible]-1-buten-3-yne gave us 1,3-di(2-diethylaminoethoxy)-1,3-butadiene (II), which on hydrolysis with 10% [illegible] acid solution gave 1,3,5-triacetylbenzene. The formation of the di(2-diethylaminoethoxy)-1,3-butadi[illegible] given case can be explained by disproportionation of the butoxy-(2-diethylaminoethoxy)-1,3-butadiene (IV) formed in the initial moment of reaction.

$$2CH{\equiv}C{-}CH{=}CHOC_4H_9 + 2HOCH_2CH_2N(C_2H_5)_2 \longrightarrow$$

$$2\left[CH_2{=}\underset{\displaystyle OCH_2CH_2N(C_2H_5)_2}{\underset{|}{C}}{-}CH{=}CHOC_4H_9\right]_{\text{(IV)}} \longrightarrow \text{(II)} + CH_2{=}C(OC_4H_9)CH{=}CHOC_4H_9$$

(either a 1,3 or a 1,4 arrangement of the alkoxy groups)

A similar disproportionation was observed earlier in the case of 1,4-dithioalkyl-1,3-butadiene [4]. As a result, a comparative study of the properties of 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) and unsubstituted 1-alkoxy-1-buten-3-ynes reveals that the nature of the reactants, as well as slight changes in the reaction conditions, both exert considerable influence on the direction of the transformations of ethynylvinyl ethers.

All of the obtained compounds are either colorless or yellow-colored mobile liquids, oxidizing to different degree in the air. The high exaltation of the molecular refraction shown by these compounds is evidently due to their containing a conjugated system of double bonds, as well as various isomers. The structure of the synthesized compounds was confirmed by hydrolysis and spectral analysis data.*

EXPERIMENTAL

Biacetylene was obtained by the Herbertz method [6] in 90-95% yield.

1-(2-Diethylaminoethoxy)-1-buten-3-yne (I). Into a three-necked flask, fitted with a stirrer, thermometer, condenser and gas-inlet tube, was charged 39 g of 2-diethylaminoethanol (b. p. 160-161°; $n^{20}D$ 1.4412), into which biacetylene, diluted with dry nitrogen, was passed for 1 hour at room temperature with stirring. The unreacted biacetylene passed through the condenser and a wash bottle containing 10% caustic solution into a trap, cooled in a mixture of acetone and dry ice. A total of 8 g of biacetylene was absorbed. The reaction mixture was allowed to stand for a day. After evaporating the unreacted biacetylene, the residue was vacuum-distilled: 1st fraction, b. p. 85-90° (25 mm), 27 g; 2nd fraction, intermediate, 0.1 g; 3rd fraction, b. p. 115° (25 mm), 15 g; tarry residue, 1.5 g. The 1st fraction was starting 2-diethylaminoethanol. Redistillation of the 3rd fraction in vacuo gave a colorless substance, which gave a positive reaction when tested with ammoniacal silver nitrate solution. Based on the elemental and spectral analysis data, the substance was 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) (yield 80-90%, based on reacted amino alcohol), and it had the following constants:

* The spectral analyses were made by B. V. Lopatin, for which the authors express their gratitude.

B. p. 99° (11 mm); $n^{20}D$ 1.4832, d^{20}_4 0.9014; MR_D 53.01. Calc. 51.49.

Found %: C 71.50, 71.45; H 10.30, 9.96; N 8.29, 8.22. $C_{10}H_{17}ON$. Calculated %: C 71.81; H 10.24; N 8.37.

Hydrolysis of 1-(2-diethylaminoethoxy)-1-buten-3-yne (I). A mixture of 10 g of ethynylvinyl ether (I) and 65 ml of 10% sulfuric acid (the amount of sulfuric acid was taken such that it was slightly in excess of the amount required to neutralize the amino group) was heated with stirring at 65-70° for 30 minutes. The lustrous yellow needle crystals that deposited (2.2 g) were filtered, washed with water, recrystallized 3 times from methanol, and dried. The substance melted at 162-163°. The mixed melting point with triacetylbenzene was not depressed. The filtrate deposited an additional amount of crystals on standing. The total yield of triacetylbenzene was 3.2 g (80%).

Reaction of 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) with 2-diethylaminoethanol. a) Into an apparatus set up for vacuum distillation was placed 4.2 g of 2-diethylaminoethanol and 0.15 g of potassium metal (in order to obtain 10% alcoholate). Then 3 g of ethynylvinyl ether (I) was added to the obtained solution. The reaction mixture was refluxed in vacuo (10 mm) for 6 hours without distilling, and then it was treated with absolute ether. The ether solution was filtered from the precipitated potassium alcoholate (0.4 g), the ether distilled off, and the residue subjected to vacuum-distillation: 1st fraction, b. p. 48-50° (5 mm), 2.4 g; 2nd fraction, intermediate, 0.4 g; 3rd fraction, b. p. 150-151° (3.5 mm), 2.9 g; tarry residue, 0.5 g. The 1st fraction was starting 2-diethylaminoethanol. The 3rd fraction was 1,3-di(2-diethylaminoethoxy)-1,3-butadiene (II) (yield 55-60%).

B. p. 151° (4 mm), $n^{20}D$ 1.4819, d^{20}_4 0.9168, MR_D 88.43. Calc. 86.32.

Found %: C 67.43, 67.29; H 11.29, 11.19; N 9.55, 9.41. $C_{16}H_{32}O_2N_2$. Calculated %: C 67.55; H 11.34; N 9.84.

b) A mixture of 6.5 g of ethynylvinyl ether (I) and 9.1 g of 2-diethylaminoethanol was refluxed in vacuo in the presence of 10% potassium alcoholate for 8 hours. The reaction mixture after suitable treatment was vacuum-distilled. We obtained 3.7 g (36%) of substance with b. p. 143° (4 mm), and $n^{20}D$ 1.4711. Based on the elemental and spectral analysis data the substance was a mixture of the di-(2-diethylaminoethoxy) derivatives of the compounds with the acetylene (15-20%), allene (10%), and diene (70%) structure.

c) The refluxing in vacuo (10 mm) of 8 g of ethynylvinyl ether (I) with 11.4 g of 2-diethylaminoethanol, containing 10% potassium alcoholate, for 22 hours gave 9.2 g (80%) of substance (V), in its analysis corresponding to the addition product of two molecules of 2-diethylaminoethanol to one molecule of the ethynylvinyl ether, and having b. p. 178-179° (4 mm), and $n^{20}D$ 1.4608.

Found %: C 65.77, 65.82; H 11.80, 11.81; N 10.58, 10.67. $C_{22}H_{47}O_3N_3$. Calculated %: C 65.78; H 11.79; N 10.46.

Spectral analysis revealed that the substance has an ethylene structure.

Hydrolysis of di-(2-diethylaminoethoxy)-1,3-butadiene (II). The hydrolysis was run in the same manner as described for the hydrolysis of ethynylvinyl ether (I). From 1.8 g of the dialkoxy-1,3-butadiene (II) we obtained 0.1 g (25%) of triacetylbenzene with m. p. 161-162°.

Reaction of 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) with butyl alcohol. A mixture of 5.3 g of butyl alcohol, 0.13 g of potassium metal (in order to obtain 5% alcoholate) and 6 g of ethynylvinyl ether (I) was heated with stirring at 125-130° for 6 hours, after which it was allowed to stand overnight. After treating with absolute ether, the solution was filtered from the precipitated potassium alcoholate (0.3 g), the ether removed by distillation, and the residue subjected to vacuum-distillation. We obtained the following fractions: 1st, b. p. up to 40° (7 mm), 2.9 g; 2nd, b. p. 137-139° (7 mm), 5 g; 3rd, b. p. 160-162° (7 mm), 0.9 g. Tarry residue, 0.7 g; intermediate fractions, 1.1 g. The 1st fraction was starting butyl alcohol. The 2nd fraction was the addition product of one molecule of butyl alcohol to one molecule of the ethynylvinyl ether (III), which represented a mixture of approximately equal amounts of the compounds with the acetylene and the allene structure (yield 50-60%).

B. p. 138-140° (10 mm), $n^{20}D$ 1.4542, d^{20}_4 0.8977, MR_D 72.83. Calc. 72.08.

Found %: C 69.55, 69.73; H 11.30, 11.31; N 5.76, 5.56. $C_{14}H_{27}O_2N$. Calculated %: C 69.60; H 11.27; N 5.80.

The 3rd fraction was 1-butoxy-4-(2-diethylaminoethoxy)-1,3-butadiene (IV) (yield 10-25%).

B. p. 153-155° (7 mm), $n^{20}D$ 1.4570, d^{20}_4 0.9010, MR_D 72.95. Calc. 73.14.

Found %: C 69.12, 68.95; H 11.31, 11.31; N 5.80, 5.60. $C_{14}H_{27}O_2N$. Calculated %: C 69.60; H 11.27; N 5.80.

We were unable to improve on the analysis results due to the difficulty of removing either decomposition or oxidation products from the materials, the presence of which was supported by the spectroscopy data.

Reaction of 1-butoxy-1-buten-3-yne with 2-diethylaminoethanol. A mixture of 4.5 g of 1-butoxy-1-buten-3-yne and 8 g of 2-diethylaminoethanol, containing 10% potassium alcoholate, was refluxed in vacuo (10-15 mm) for 15 hours. The reaction mixture was treated with ether, the solution filtered from the deposited potassium alcoholate (0.9 g), the ether distilled off, and the residue subjected to vacuum-distillation. We obtained the following fractions: 1st, b. p. 80-90° (22 mm), 6.8 g; 2nd, b. p. 60-127° (1.5 mm), 1.5 g; 3rd, b. p. 127-129° (1.5 mm), 1.6 g; tarry residue, 0.9 g. The 1st fraction was a mixture of the starting materials; the 2nd fraction was a mixture of the starting materials and reaction products; the 3rd fraction, based on the elemental and spectral analysis data, was di-(2-diethylaminoethoxy)-1,3-butadiene (II) (yield 30%).

B. p. 160-161° (4 mm); $n^{20}D$ 1.4769, d^{20}_4 0.9143, MR_D 87.89. Calc. 86.32.

Found %: C 67.31, 67.53; H 11.11, 11.01; N 9.78, 9.64. $C_{16}H_{32}O_2N_2$. Calculated %: C 67.55; H 11.34; N 9.84.

The hydrolysis of 0.8 g of the isolated substance with 7 ml of 10% sulfuric acid solution (1 hour, 60°) led to the formation of 0.05 g (30%) of triacetylbenzene with m. p. 160°. The mixed melting point was not depressed.

Some difference in the physical constants of the investigated substance with the constants of the di-(2-diethylaminoethoxy)-1,3-butadiene (II) obtained earlier can be explained by the cleavage of the first into the geometric isomers.

Substance	Absorption band frequencies of substances (in cm^{-1})			
	1	2	3	4
I	2120	—	1628	—
II	—	1667	1621	—
II *	—	—	1630	1555
II **	2200	1936	—	1596, 1546
III	2220	1930	—	—
IV	—	1685 ***	1610	—
V	—	1635 **** weak	—	—
VI	—	—	1645	1566

* The dialkoxy-1,3-butadiene (II) was obtained by disproportionation. Cleavage into the cis- and trans-isomers was observed in the given case.

** Dialkoxy-1,3-butadiene (II) contaminated with products having the acetylene and the allene structure.

*** The absorption band at 1685 cm^{-1} belongs to either decomposition or oxidation products.

**** The intensity of the absorption band is considerably less than in the spectra of similar compounds having the diene structure.

Reaction of 1-(2-diethylaminoethoxy)-1-buten-3-yne (I) with ethyl mercaptan. A mixture of 6.9 g of (I) and 4.4 g of ethyl mercaptan was heated with stirring at 70-80° for 6 hours, and then it was vacuum-distilled. The unreacted ethyl mercaptan (3 g) was collected in a trap, cooled in a mixture of acetone and dry ice. We obtained the following fractions: 1st, b. p. 90-100° (10 mm), 3.6 g; 2nd, intermediate, 0.2 g; 3rd, b. p. 164° (10 mm), 2 g; residue, 0.8 g. The 1st fraction was starting ethynylvinyl ether (I); the 3rd fraction was ethylmercapto-(2-diethylaminoethoxy)-1,3-butadiene (VI), the diene structure of which was shown spectroscopically (yield 60-70%, based on reacted ethynylvinyl ether).

B. p. 152° (7 mm), $n^{20}D$ 1.5290, d^{20}_4 0.9550, MR_D 73.91. Calc. 70.23.

Found %: C 62.67, 62.77; H 9.98, 10.06; S 13.66, 13.71. $C_{12}H_{23}ONS$. Calculated %: C 62.83; H 10.10; S 13.94.

Spectral analysis data. The patterns of all of the compounds were taken in the 2500-1500 cm^{-1} region, using an IKS-11 infrared spectrometer and NaCl prism. The obtained data are summarized in the table.

SUMMARY

1. The conditions for the synthesis of 1-(2-diethylaminoethoxy)-1-buten-3-yne from biacetylene and 2-diethylaminoethanol in 80-90% yield were ascertained, and some of the transformations of the compound were studied.

2. The peculiarities in the behavior of 2-diethylaminoethanol and 1-(2-diethylaminoethoxy)-1-buten-3-yne in the given reactions, when compared respectively with the unsubstituted alkyl alcohols and 1-alkoxy-1-buten-3-ynes, were ascertained.

3. It was shown that, depending on the reaction conditions, the reaction of 1-(2-diethylaminoethoxy)-1-buten-3-yne with aliphatic alcohols goes in several directions: with the formation of either dialkoxy derivatives, having dienic, allenic and acetylenic structures, or trialkoxy derivatives.

4. We prepared and characterized di-(2-diethylaminoethoxy)-1,3-butadiene, butoxy-(2-diethylaminoethoxy)-1,3-butadiene, the butoxy derivative of 1-(2-diethylaminoethoxy)-1-buten-3-yne, being a mixture of compounds having the acetylene and the allene structure, and tri-(2-diethylaminoethoxy)-butene.

5. The reaction of 1-(2-diethylaminoethoxy)-1-buten-3-yne with ethyl mercaptan under the given conditions leads to obtaining only ethylmercapto-(2-diethylaminoethoxy)-1,3-butadiene.

6. It was shown that it is possible for butoxy-(2-diethylaminoethoxy)-1,3-butadiene to disproportionate into the symmetrical dialkoxy-1,3-butadienes.

LITERATURE CITED

[1] M. F. Shostakovskii, A. V. Bogdanova, and G. K. Krasil'nikova, Doklady Akad. Nauk SSSR 114, 1250 (1957).*

[2] M. F. Shostakovskii, A. V. Bogdanova, and G. I. Plotnikova, Doklady Akad. Nauk SSSR 120, 301 (1958).*

[3] I. I. Guseinov, E. N. Prilezhaeva, and M. F. Shostakovskii, Zhur. Obshchei Khim. 29, 3223 (1959).*

[4] E. N. Prilezhaeva, I. I. Guseinov, B. V. Lopatin, and M. F. Shostakovskii, Zhur. Obshchei Khim. 29, 3227 (1959).*

[5] A. Auerhahn and R. Stadler, I. G. Farbenind. Akt. Ges., Chem. Zentr. (1935), I, 2255; German Patent 601,822 (1934); French Patent 765,741 (1934).

[6] T. Herbertz, Ber. 85, 475 (1952).

[7] W. Franke, R. Kraft, D. Tietjen, and H. Weber, Ber. 86, 794 (1953).

* Original Russian pagination. See C. B. translation.

[8] German Patent 871,006 (1953).

[9] German Patent 859,307 (1952).

[10] J. W. Copenhaver and M. H. Bigelow, Acetylene and carbon monoxide chemistry (1949), 305.

[11] M. F. Shostakovskii, I. A. Chekulaeva, and L. V. Kondrat'eva, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk (1958), 794.*

* Original Russian pagination. See C. B. translation.

SYNTHESIS AND TRANSFORMATIONS OF SUBSTITUTED VINYL ETHERS

X. SYNTHESIS AND TRANSFORMATIONS OF PROPENYL AND ISOPROPENYL PHENYL SULFIDES

N. K. Kul'bovskaya, E. P. Gracheva, and M. F. Shostakovskii

Institute of Organic Chemistry, Academy of Sciences of the USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 81-86, January, 1960

Original article submitted January 15, 1959

In this paper we investigated the reaction of methylacetylene with thiophenol in alkaline medium. Earlier we had shown that methylacetylene can be used in the vinylation of alcohols [1] and phenols [2], and here the main reaction products are respectively isopropenyl alkyl and isopropenyl aryl ethers. In contrast to this, the vinylation of thiophenol under the conditions of the Favorskii – Shostakovskii reaction leads to obtaining two compounds, namely isopropenyl (I) and propenyl (II) phenyl sulfides.

$$C_6H_5SH + CH_3{-}C{\equiv}CH \rightarrow \underset{\text{(I)}}{CH_2{=}\underset{\displaystyle CH_3}{\overset{|}{C}}{-}SC_6H_5} \qquad (1)$$

$$C_6H_5SH + CH_3{-}C{\equiv}CH \rightarrow \underset{\text{(II)}}{CH_3CH{=}CHSC_6H_5} \qquad (2)$$

A similar dual manner in the addition of a thiol to a substituted acetylene was described for the case of 1-heptyne and p-toluenethiol [3]. Here it was shown that aromatic thiols in the presence of alkali add stereospecifically to acetylenes via nucleophilic addition [3, 4].

In the example described by us, reactions (1) and (2) are nucleophilic addition reactions, although direction (2) leads to an addition product contrary to the Markovnikov rule. In our experiments, the presence of hydroquinone in the reaction medium failed to suppress reaction (2). Stereospecific addition of the thiol according to reaction (2) leads to one stereoisomer. This may be judged on the basis of oxidizing propenyl phenyl sulfide, where only the crystalline propenyl phenyl sulfone $CH_3CH=CHSO_2C_6H_5$ (III) is obtained, whose melting point corresponds to the higher melting isomer, probably the trans [5]. In addition, in the infrared spectrum of the propenyl phenyl sulfide the double bond absorption band at 1600 cm^{-1} is not divided, which also indicates the presence of only one isomer.

The mixture of sulfides obtained in the vinylation of thiophenol was separated by fractional distillation through a column in vacuo. The higher boiling fraction had constants that were close to those given in the literature for propenyl phenyl sulfide [5, 6]. The lower boiling fraction was characterized as being isopropenyl phenyl sulfide. This compound had been synthesized earlier by the decomposition of β-thiophenylcrotonic acid [7]. But since the only constant given for the compound was a boiling point of 206-210°, for identification we converted the isopropenyl phenyl sulfide to the known isopropyl phenyl sulfone (IV) [8] by the scheme

$$CH_2{=}\underset{\displaystyle CH_3}{\underset{|}{C}}{-}SC_6H_5 \xrightarrow{H_2O_2} CH_2{=}\underset{\displaystyle CH_3}{\underset{|}{C}}{-}SO_2C_6H_5 \xrightarrow{H_2} (CH_3)_2CHSO_2C_6H_5$$

(IV)

In contrast to the crystalline sulfones, the isopropenyl and isopropyl phenyl sulfones obtained from propenyl phenyl sulfide are oily substances.

The infrared spectra* confirmed the structure assigned to the sulfides. The isopropenyl phenyl sulfide specimen showed an absorption band for the in-plane deformation vibration of the CH_2 group with a maximum at 1420 cm^{-1} [9]. This band is absent in the case of the propenyl phenyl sulfide, for which reason an absorption band for the out-of-plane deformation vibration of the CH group is found at 970-960 cm^{-1}.

The hydrolysis of the propenyl and isopropenyl phenyl sulfides leads respectively to propionaldehyde and acetone, which were characterized as the dinitrophenylhydrazones. This reaction also supports the structure assigned to the sulfides.

We tried to apply the reaction of quantitative decomposition with alcoholic mercuric chloride solution [10] to the synthesized sulfides. But, here it proved that this reaction can serve only for the quantitative determination of isopropenyl phenyl sulfide. When a weighed sample of isopropenyl phenyl sulfide is mixed with a solution of mercuric chloride a precipitate of phenylmercuric chloride deposits within 30 seconds, and after standing for a day 95% (of the theoretical) of the hydrochloric acid titrates. In the case of propenyl phenyl sulfide a small amount of precipitate deposits after approximately 30 minutes, and after a day only 8-9% of the acid titrates. The percent of titratable acid increases on standing. This reaction can be used for the rapid qualitative differentiation of the indicated sulfides.

Both the propenyl and the isopropenyl phenyl sulfides add thiols in the presence of a radical catalyst [10], in which connection reaction with thiophenol gives the same 1,2-diphenylmercaptopropane $C_6H_5SCH_2CH(CH_3)SC_6H_5$ (V) in both cases, while reaction with ethyl mercaptan gives the isomeric dithioethers (VI and VII).

$$\text{(I)} + C_2H_5SH \longrightarrow C_2H_5SCH_2{-}\underset{\displaystyle CH_3}{\underset{|}{C}}HSC_6H_5$$

(VI)

$$\text{(II)} + C_2H_5SH \longrightarrow C_2H_5S\underset{\displaystyle CH_3}{\underset{|}{C}}H{-}CH_2SC_6H_5$$

(VII)

Isopropenyl phenyl sulfide was studied in reactions of the ionic type for the purpose of comparison with the properties of isopropenyl phenyl ether. It proved that the sulfur and oxygen analogs behave in the same manner in ionic reactions. Thus, in the presence of an ionic catalyst (SO_2) isopropenyl phenyl sulfide reacts with ethyl mercaptan in a manner that is analogous to the reaction of isopropenyl phenyl ether with alcohols [11]. Isopropenyl ethyl sulfide was isolated from the reaction mixture, thus indicating that indirect vinylation of the ethyl mercaptan had occurred.

$$\text{(I)} + C_2H_5SH \xrightarrow{SO_2} \left[\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>C<\!\!\begin{matrix} SC_6H_5 \\ SC_2H_5 \end{matrix}\right] \longrightarrow CH_2{=}\underset{\displaystyle CH_3}{\underset{|}{C}}{-}SC_2H_5 + C_6H_5SH$$

The hydrochlorination of isopropenyl phenyl sulfide leads to the formation of α-chloroisopropyl phenyl sulfide, which, similar to α-chloroisopropyl phenyl ether [11], is an unstable compound. α-Chloroisopropyl phenyl sulfide was characterized by its conversion to the known tert-amyl phenyl sulfide [12].

* The spectra were taken by B. V. Lopatin, for which the authors wish to express their thanks.

$$\text{(I)} \xrightarrow{HCl} (CH_3)_2\underset{\displaystyle Cl}{\underset{|}{C}}\!-\!SC_6H_5 \xrightarrow{RMgBr} (CH_3)_2\underset{\displaystyle R}{\underset{|}{C}}SC_6H_5$$

$R = C_2H_5,\ C_3H_7$

EXPERIMENTAL

1. Reaction of methylacetylene with thiophenol. The experiments were run in a rotated 250 ml autoclave by the method described in [2]. Into the autoclave were charged 55 g of thiophenol, 60 g of methylacetylene, 55 ml of dioxane and 5.61 g of KOH, and the mixture was heated for 2 hours at 150-160°. The maximum pressure was 46 atm, and the minimum was 34 atm. The discharged product was diluted with diethyl ether and then washed with water. The ether layer was dried over Na_2SO_4 and then distilled from a Favorskii flask. First fraction, b. p. 81-97° (20 mm), 6.2 g; 2nd fraction, b. p. 97-120° (20 mm), 48 g. The residue, a brown liquid, weighed 16 g. The 2nd fraction was fractionated through a column with an efficiency of 20 theoretical plates. The following fractions were obtained:

First b. p. 98-101° (20 mm), 22.1 g (29%), $n^{20}D$ 1.5690. Second b. p. 101-111° (20 mm), 8.7 g (1.4%), $n^{20}D$ 1.5768; Third b. p. 111-113° (20 mm), 9.5 g (12.5%), $n^{20}D$ 1.5841.

The first fraction is isopropenyl phenyl sulfide (I):

B. p. 68-69° (6 mm), 74-75° (7.5 mm), $n^{20}D$ 1.5690, d^{20}_4 1.0162, MR_D 48.45; Calc. 48.09.*

Found %: C 71.88, 71.64; H 6.72, 6.65; S 21.08, 21.11. $C_9H_{10}S$. Calculated %: C 71.98; H 6.71; S 21.34.

The third fraction is propenyl phenyl sulfide (II):

B. p. 111-113° (20 mm), $n^{20}D$ 1.5849, d^{20}_4 1.0302.

Found %: C 71.87, 71.99; H 6.75, 6.76; S 20.97, 20.87. $C_9H_{10}S$. Calculated %: C 71.98; H 6.71; S 21.34.

Literature data: b. p. 79-80° (3 mm), $n^{20}D$ 1.5850, d^{20}_4 1.0328 [5], b. p. 61-69° (1.3 mm), $n^{20}D$ 1.5850-1.5860 [6].

2. Oxidation of isopropenyl phenyl sulfide (I). Into a three-necked flask, fitted with a stirrer, condenser and thermometer, were charged 10.5 g of isopropenyl phenyl sulfide, 0.5 g of pyridine and 80 ml of 28% hydrogen peroxide. The oxidation was run for 60 hours at 80° [14]. The lower layer was separated, diluted with ether, washed with water, dried over K_2CO_3, and distilled. We obtained 6.7 g (53%) of isopropenyl phenyl sulfone:

B. p. 142° (4.5 mm), $n^{20}D$ 1.5470, d^{20}_4 1.1872, MR_D 48.67. Calc. 48.26.

Found %: C 59.22, 59.23; H 5.66, 5.76; S 17.50, 17.43. $C_9H_{10}O_2S$. Calculated %: C 59.30; H 5.54; S 17.59.

3. Oxidation of propenyl phenyl sulfide (II). Operating in the same manner as above, the oxidation of 9.5 g of propenyl phenyl sulfide for 48 hours gave 8.9 g (77%) of propenyl phenyl sulfone. The crystals were dissolved in alcohol and reprecipitated with water. M. p. 69.5-70°.**

Found %: C 59.29, 59.26; H 5.44, 5.49; S 17.62, 17.42. $C_9H_{10}O_2S$. Calculated %: C 59.30; H 5.54; S 17.59.

4. Hydrogenation of isopropenyl phenyl sulfone. A charge of 2 g Pd/C (5%), 50 ml of ethanol and 7.0 g of isopropenyl phenyl sulfone was placed in a hydrogenation bottle. The equivalent amount of hydrogen was absorbed in 1.5 hours. The catalyst was filtered, washed with hot ethanol, and the ethanol was combined with the main portion. Distillation gave 6.5 g of the sulfone (91%).

* The atomic refraction of sulfur was taken equal to 8.4 [13].

** The literature [5] gives m. p. 68.5-69°.

B. p. 145° (5 mm),* $n^{20}D$ 1.5320, d^{20}_4 1.1622, MR_D 49.11; Calc. 48.72.

Found %: C 58.64, 58.82; H 6.50, 6.47; S 17.20, 17.19. $C_9H_{12}O_2S$. Calculated %: C 58.65; H 6.56; S 17.40.

5. Hydrogenation of propenyl phenyl sulfone. Three grams of the substance was hydrogenated in 40 ml of alcohol using 1 g of Pd/C (5%). We obtained 2.8 g (85%) of propyl phenyl sulfone. The compound was recrystallized from 40% acetic acid. M. p. 43-45°. The literature [15] gives m. p. 41.5-43.5° and 46°.

6. Hydrolysis of isopropenyl phenyl sulfide. The hydrolysis was run by the earlier described method [16]. Six grams of the sulfide in 200 ml of ethanol was heated with stirring for 2 hours with 40 ml of 6 N hydrochloric acid. The acetone formed in the reaction was blown out with nitrogen into a trap containing an aqueous alcohol solution of 2,4-dinitrophenylhydrazine. The hydrazone precipitate was filtered and then recrystallized from alcohol. We obtained 1.5 g of crystals, m. p. 125°. The mixed melting point with authentic acetone hydrazone was not depressed. Acid hydrolysis of 4.5 g of the propenyl phenyl sulfide by the above described method gave 0.91 g of propionaldehyde hydrazone with m. p. 154-154.5°.

7. "Mercuric chloride" titration of isopropenyl phenyl sulfide [10]. A sample of the sulfide (0.1-0.2 g) was added to 5 ml of a 20% alcohol solution of mercuric chloride. A copious precipitate separated within 0.5 minutes. After standing for a day, the liberated acid was titrated with 0.1 N NaOH solution in the presence of methyl orange. The amount of titratable acid was found to be 95-95.5%.

8. Decomposition of propenyl phenyl sulfide with mercuric chloride. After adding the sulfide sample (0.1-0.2 g) to 5 ml of the mercuric chloride solution, a precipitate slowly began to appear after 20-30 minutes. After standing for a day, the titratable hydrochloric acid was 7.9-9.4%, after two days it was 23-24%, and after 6 days it was 60-61%.

9. 1-Ethylmercapto-2-phenylmercaptopropane (VI). Into an ampul were charged 8 g of isopropenyl phenyl sulfide, 3.3 g of ethyl mercaptan, and 0.1 g of azobisisobutyronitrile. The ampul was sealed and heated for 4 hours at 80°. Fractional distillation of the reaction mixture gave 9.2 g (81%) of the disulfide:

B. p. 129-130° (5 mm), 114-115° (3 mm), $n^{20}D$ 1.5715, d^{20}_4 1.0582, MR_D 65.95; Calc. 65.72.**

Found %: C 62.40, 62.48; H 7.53, 7.57; S 29.90, 30.11. $C_{11}H_{16}S_2$. Calculated %: C 62.23; H 7.59; S 30.21.

10. 1-Phenylmercapto-2-ethylmercaptopropane (VII). Using the same conditions as in Expt. 9, from 9.1 g of propenyl phenyl sulfide, 3.75 g of ethyl mercaptan and 0.1 g of azobisisobutyronitrile we obtained 10.5 g (82%) of the disulfide:

B. p. 134-135° (5 mm), 120° (3 mm), $n^{20}D$ 1.5725, d^{20}_4 1.0592, MR_D 66.06; Calc. 65.72.

Found %: C 62.31, 62.47; H 7.53, 7.58; S 30.08, 29.81. $C_{11}H_{16}S_2$. Calculated %: C 62.23; H 7.59; S 30.21.

11. 1,2-Diphenylmercaptopropane (V) was obtained in a similar manner from thiophenol and isopropenyl phenyl sulfide (or propenyl phenyl sulfide) in 82% yield.

B. p. 197-198° (7 mm), $n^{20}D$ 1.6218, d^{20}_4 1.1252, MR_D 81.47; Calc. 81.21.

Found %: C 69.08, 69.15; H 6.29, 6.25; S 24.40, 24.47. $C_{15}H_{16}S_2$. Calculated %: C 69.17; H 6.18; S 24.62.

12. Reaction of isopropenyl phenyl sulfide with ethyl mercaptan in the presence of sulfur dioxide. Sulfur dioxide was passed for 3 minutes into an ampul containing 12.4 g of ethyl mercaptan and cooled in a mixture of acetone and dry ice. After adding 23 g of isopropenyl phenyl sulfide, the ampul was immersed in liquid nitrogen, evacuated, sealed, and heated at 100° for 9 hours. After opening the ampul, the contents were vacuum-distilled.

* The literature [8] gives b. p. 145-150° (1 mm), 110-120° (0.01 mm).

** The atomic refraction of sulfur was taken equal to 7.92 and 8.4 for different sulfur atoms [13].

The distillate was a mixture of thiophenol and isopropenyl phenyl sulfide, boiling in the range 67-100° (27 mm). The trap contained 7 g of substance, from which we isolated 1.6 g of isopropenyl ethyl sulfide with b. p. 112-114°, $n^{20}D$ 1.4755 and d^{20}_4 0.8728.

13. α-Chloroisopropyl phenyl sulfide. In a three-necked flask, fitted with a stirrer, thermometer, condenser and gas-inlet tube, was placed 25 g of isopropenyl phenyl sulfide. Then with cooling to − 20° a stream of hydrogen chloride was passed in until it began to escape through the condenser. After this the excess hydrogen chloride was removed from the dark liquid using a water-jet pump. The increase in weight was 5.1 g. The material was used as a sirup in the reactions.

14. Hydrolysis of α-chloroisopropyl phenyl sulfide. Into an Erlenmeyer flask with ground-glass stopper were charged 50 ml of water and the weighed sample of α-chloroisopropyl phenyl sulfide (0.3-0.4 g). After shaking, the hydrochloric acid was titrated with 0.1 N NaOH solution. The amount of α-chloride was 94-95%.

15. Tert-Amyl phenyl sulfide. The Grignard reagent from 4 g of magnesium and 17.6 g of ethyl bromide was added in drops to 30.1 g of α-chloroisopropyl phenyl sulfide, diluted with diethyl ether. The flask was cooled in ice water. The thick reaction mass was allowed to stand overnight. Then it was decomposed with 10% HCl solution, and the ether layer was washed with sodium carbonate solution, dried, and distilled. We isolated 7.2 g of tert-amyl phenyl sulfide:

B. p. 96-98° (9 mm), $n^{20}D$ 1.5387, d^{20}_4 0.9713.

Found %: C 73.02, 73.12; H 8.75, 8.82; S 17.95, 17.89. $C_{11}H_{16}S$. Calculated %: C 73.29; H 8.94; S 17.72.

Literature data: b. p. 91-91.5° (6 mm), $n^{20}D$ 1.5351, d^{20}_4 0.9679 [12].

Operating in a similar manner, we synthesized 1,1-dimethylbutyl phenyl sulfide in 19% yield:

B. p. 83-84° (2 mm), $n^{20}D$ 1.5312, d^{20}_4 0.9575, MR_D 62.81; Calc. 62.41.

Found %: C 74.00, 74.09; H 9.50, 9.30; S 16.42, 16.21. $C_{12}H_{18}S$. Calculated %: C 74.16; H 9.33; S 16.50.

SUMMARY

1. The reaction of thiophenol with methylacetylene in alkaline medium gives a mixture of propenyl and isopropenyl phenyl sulfides. The structure of the sulfides was proved by chemical transformations and the infrared spectra.

2. It was shown that the technique of decomposition with an alcohol solution of mercuric chloride can be used for the quantitative determination of isopropenyl phenyl sulfide.

3. In the presence of a radical catalyst the propenyl and isopropenyl phenyl sulfides add thiols with the formation of dithioethers.

4. It was shown that isopropenyl phenyl sulfide behaves in the same manner as the oxygen analog, isopropenyl phenyl ether, in ionic reactions.

5. The following new compounds were synthesized: isopropenyl phenyl sulfone, α-chloroisopropyl phenyl sulfide, 1,1-dimethylbutyl phenyl sulfide, 1,2-diphenylmercaptopropane, 1-ethylmercapto-2-phenyl-mercaptopropane, and 1-phenylmercapto-2-ethylmercaptopropane.

LITERATURE CITED

[1] M. F. Shostakovskii and E. P. Gracheva, Zhur. Obshchei Khim. 23, 1153, 1320 (1953).*

[2] M. F. Shostakovskii, E. P. Gracheva, and N. K. Kul'bovskaya, Zhur. Obshchei Khim. 28, 1253 (1958).*

[3] W. E. Truce and J. A. Simms, J. Am. Chem. Soc. 78, 2756 (1956).

* Original Russian pagination. See C. B. translation.

[4] W. E. Truce, J. A. Simms, and M. M. Boudakian, J. Am. Chem. Soc. 78, 695 (1956).

[5] E. N. Karaulova, D. Sh. Meilanova, and G. D. Gal'pern, Doklady Akad. Nauk SSSR 113, 1280 (1957).*

[6] D. S. Tarbell and M. A. McCall, J. Am. Chem. Soc. 74, 48 (1952).

[7] R. Escales and E. Baumann, Ber. 19, 1792 (1886).

[8] W. Autenrieth, Lieb. Ann. 254, 232 (1889); W. A. Baldwin and R. Robinson, J. Chem. Soc. (1932), 1446; H. Böhme and H. J. Gran, Lieb. Ann. 577, 74 (1952).

[9] L. J. Bellamy, Infrared Spectra of Complex Molecules [Russian translation] (Moscow, 1957), pp. 54, 59.

[10] M. F. Shostakovskii, E. N. Prilezhaeva, and N. I. Uvarova, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk (1954), 526;*(1955), 906.*

[11] M. F. Shostakovskii, E. P. Gracheva, and N. K. Kul'bovskaya, Zhur. Obshchei Khim. 28, 2341, 2344 (1958).*

[12] V. N. Ipatiev, H. Pines, and B. S. Friedman, J. Am. Chem. Soc. 60, 2732 (1938).

[13] A. I. Vogel, J. Chem. Soc. (1948), 1820.

[14] W. Reppe, Lieb. Ann. 601, 118 (1956).

[15] F. G. Bordwell, H. M. Andersen, and B. M. Pitt, J. Am. Chem. Soc. 76, 1085 (1954); W. A. Baldwin and R. Robinson, J. Chem. Soc. (1932), 1446.

[16] D. S. Tarbell and W. E. Lovett, J. Am. Chem. Soc. 78, 2263 (1956).

* Original Russian pagination. See C. B. translation.

SYNTHESIS OF ALIPHATIC AROMATIC SILANES AND THEIR DEHYDROGENATION

A. A. Balandin, A. D. Petrov, G. M. Marukyan, E. A. Chernyshev, I. I. Brusov, S. I. Sadykh-zade, R. G. Seimovich, and N. G. Tolstikova

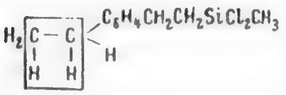
N. D. Zelinskii Institute of Organic Chemistry, Academy of Sciences of the USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 87-91, January, 1960

Original article submitted January 21, 1959

The chemistry of unsaturated silanes is of great scientific and practical interest. Similar to styrene and its homologs, unsaturated aliphatic aromatic organosilicon compounds are easily polymerized, and their copolymers possess valuable technical properties [1]. In recent years many papers have appeared in the literature on the synthesis of unsaturated organosilicon compounds, mainly in the aliphatic series [2]. In studying the dehydrogenation of tetraethylsilane on chromium catalyst it was found by B. N. Dolgov and co-workers [3] that the compound begins to decompose as low as 510-530°, and the formation of triethylvinyl silane fails to occur. Later Dolgov and co-workers [4] subjected trimethylbutylsilane to dehydrogenation at 550-575°, and here they obtained up to an 8.6% yield of trimethylbutenylsilane, based on trimethylbutylsilane passed through.

Information on the catalytic dehydrogenation of aliphatic aromatic silanes is lacking in the literature, for which reason we deemed it interesting to synthesize the latter and subject them to dehydrogenation. In principle, the dehydrogenation of aliphatic aromatic silanes to the corresponding silicon-containing styrenes differs but slightly from the dehydrogenation of monoalkylbenzenes. According to the multiplet theory [5], for dehydrogenation to take place the side chain of the aliphatic aromatic silane should be located in doublet fashion on the surface of the catalyst atom.



Together with dehydrogenation, where the C–H bonds are activated, it is also possible for cleavage to occur with a rupture of the C–C bonds, which is confirmed by the presence of low-boiling products in the liquid catalyzate, and of ethylene and methane in the escaping gas.

To obtain the aliphatic aromatic silanes we synthesized divinylbenzene and ethylstyrene by the catalytic dehydrogenation of diethylbenzene (mixture of the three isomers): b. p. 179-185°, $n^{20}D$ 1.4939 and d^{20}_4 0.8590.

Diethylbenzene was passed over a mixed oxide catalyst (A) at 600-625° in the presence of steam. The dehydrogenation was run in the standard setup for the synthesis of divinylbenzene [6]. To obtain the silanes, we took the diethylbenzene catalyzate, $n^{20}D$ 1.5305, containing 20% divinylbenzene and 40% ethylstyrene. The amount of divinylbenzene and ethylstyrene in the catalyzate was determined by the nitrosite method [7].

$C_2H_5C_6H_4CH_2CH_2SiCl_2CH_3$ (I) $CH_3Cl_2SiCH_2CH_2C_6H_4CH_2CH_2SiCl_2CH_3$ (II)

$$\text{(I)} \xrightarrow{-H_2} \text{(IV)}$$

$(CH_3)_3SiC_6H_4C_2H_5$ (III) $CH_2{=}CHC_6H_4CH_2CH_2SiCl_2CH_3$ (IV)

EXPERIMENTAL

1-Ethylphenyl-2-methyldichlorosilylethane (I). In a three-necked flask, fitted with a reflux condenser, mechanical stirrer and dropping funnel, was placed 250 g of a mixture composed of 40% ethylstyrene, 20% divinylbenzene and 40% diethylbenzene. Then 1 ml of an 0.1 N isopropyl alcohol solution of H_2PtCl_6 was added to the mixture with stirring. This was followed by the addition of 150 g of methyldichlorosilane with stirring, after which the mixture was heated slowly in 2 hours to 65°. After distilling off the unreacted methyldichlorosilane, the residue (385 g) was vacuum-distilled. Here we isolated 142 g of a fraction with b. p. 87-89° (1 mm), $n^{20}D$ 1.5140 and d^{20}_4 1.0937, which was 1-ethylphenyl-2-methyldichlorosilylethane (I).

Found %: C 53.26, 53.65; H 6.54, 6.53; Cl 28.62, 28.84; Si 11.56, 11.39. $C_{11}H_{16}Cl_2Si$. Calculated %: C 53.46; H 6.88; Cl 28.33; Si 11.35.

The second fraction (56 g), b. p. 140-141° (1 mm), $n^{20}D$ 1.5220, and d^{20}_4 1.1073, was bis(2-methyldichlorosilylethyl)benzene (II).

Found %: Si 14.89. $C_{12}H_{18}Cl_4Si_2$. Calculated %: Si 15.50.

Trimethylsilylethylbenzene (III). $(CH_3)_3SiCl$ (1.5 moles) was added in 45 minutes to the Grignard reagent obtained from 160 g of bromo-ethylbenzene and 20.6 g of Mg in 300 ml of absolute ether. A slight heating up of the mixture was observed, as well as the formation of a precipitate. The mixture was heated on the water bath for 4 hours, and then worked up in conventional manner. Fractional distillation gave 38 g of (III):

B. p. 205-208° (752 mm), $n^{20}D$ 1.4905, d^{20}_4 0.8843, MR_D 58.81; Calc. 59.58.

Found %: C 73.95, 74.10; H 10.09, 10.12; Si 15.42, 15.80. $C_{11}H_{18}Si$. Calculated %: C 74.16; H 10.11; Si 15.73.

The dehydrogenation of 1-ethylphenyl-2-methyldichlorosilylethane (I) was run in a conventional catalytic furnace, using a mixed oxide catalyst (A), at atmospheric pressure, without a diluent. The space velocity was 0.15-0.35 hr^{-1}. The temperature was measured with the thermocouple located inside the catalyst layer. 1-Ethylphenyl-2-methyldichlorosilylethane was fed from a buret into the quartz reaction tube (d 15 mm), contained in an inclined electric furnace. First, the system was blown with nitrogen to completely remove air and moisture. The liquid reaction products were collected in the receiver, while the gases and uncondensed vapors passed through a reflux condenser into a graduated gasometer containing saturated NaCl solution. The escaping gases were analyzed in an Orsat apparatus and also chromatographically using a special column [8]. The amount of unsaturates in the catalyzate was determined by bromine titration [9]. The results of the experiments (see Table 1) revealed that the dehydrogenation, as was predicted by the multiplet theory, might possibly

TABLE 1

Dehydrogenation of 1-Ethylphenyl-2-methyldichlorosilylethane (I) on Mixed Oxide Catalyst A (Catalyst Volume 25 ml)

Expt. No.	Experiment temperature	Reaction time (hr)	Space velocity of adding the compound (hr^{-1})	Catalyzate yield (wt. %)	Amount of unsaturates	
					in catalyzate (%)	in the gas (vol. %)
1	536—538°	2	0.25	56.5	15	1.2
2	500	2.5	0.35	94.0	26.3	0.8
3	600	2.5	0.30	87.3	50.1	0.2
4	500—509	2.5	0.2	93.7	18.7	—
5	520	3	0.15	76.4	12.0	—
6	490—505	3	0.24	87.2	21.1	—
7	502—507	3	0.265	89.3	27.7	—

go at a temperature even lower than that ordinarily required for the dehydrogenation of ethylbenzene. The catalyst (A) used by us was the same as that used for the dehydrogenation of ethylbenzene and its homologs. As the data in Table 1 show, the substance decomposes at 536-538°, the yield of catalyzate is 56.5%, and the amount of unsaturates in the gas is 1.2%. When the temperature is reduced to 500° the yield of catalyzate is 87-89.4%, and the amount of unsaturates in the gas is 0.2-0.8 %. Elemental analysis of the catalyzate revealed that both chlorine and silicon are retained in the molecule. Due to the closeness of the boiling points, the starting substance and the dehydrogenation product could not be separated by fractional distillation. In addition, the distillation of the catalyzate, even in the presence of a stabilizer, caused a substantial portion of the unsaturated products to polymerize. The fractional distillation of 19 g of the catalyzate from Expt. 7 gave the following fractions, with the constants:

1st, b. p. 66-140° (23 mm), 2.6 g, $n^{20}D$ 1.5062, amount of unsaturates 27.8%; 2nd, b. p. 141-143° (23 mm), 12 g, $n^{20}D$ 1.5181, amount of unsaturates 31.7%; 3rd, b. p. 161° (26 mm), 0.5 g, $n^{20}D$ 1.5273, amount of unsaturates 41.4%; the residue (1.8 g) was a polymer.

The 2nd fraction was a mixture of starting substance (I) and silicon-containing styrene (IV).

Found %: C 53.65, 53.82; H 6.49, 6.51; Cl 27.98, 27.81; Si 11.71, 11.95. $C_{11}H_{14}Cl_2Si$. Calculated %: C 53.88; H 5.71; Cl 28.99; Si 11.42. $C_{11}H_{16}Cl_2Si$. Calculated %: C 53.46; H 6.88; Cl 28.33; Si 11.33.

In Expt. 3 (Table 1) the amount of unsaturates in the catalyzate reached 50.1%, but then the amount of unsaturates dropped sharply (Expts. 4-7), apparently because the catalyst was poisoned by the reaction products; the catalyst on removal proved to be highly disintegrated, although normally it is mechanically stable. We also tested a catalyst prepared from Cu – Al alloy (leached) for the indicated reaction. The dehydrogenation of 1-ethylphenyl-2-methyldichlorosilylethane (I) was run at 500° and 445-450°, using a feed rate of 0.30-0.50 hr^{-1}. These experiments revealed that a temperature of 500° is slightly too high for this catalyst: a major decomposition of the substance occurs, and the catalyzate yield is only 56%. The amount of unsaturates in the catalyzate is 21.8%. At 445-450° the catalyzate yield is 88%. The amount of unsaturates in the catalyzate is 24.8%. It can be seen that a temperature of 445-450° is the optimum for this catalyst. The search for catalysts for the dehydrogenation of aliphatic aromatic silanes continues.

Dehydrogenation of bis(2-methyldichlorosilylethyl)benzene (II). This hydrogenation was run at 495-505° using mixed oxide catalyst (B) and a silane feed-rate of 0.28 hr^{-1}. The total amount of substance passed through was 13 ml, but here we failed to obtain a liquid catalyzate; instead we collected 1.28 liters of a gas containing 5% ethylene and 20% hydrogen. The second experiment was run at 450°, and here 17 g of the compound was passed over the catalyst, but again we failed to obtain a liquid catalyzate. After the two experiments, it was found that the catalyst tube contained a rubberlike polymer.

The dehydrogenation of trimethylsilylethylbenzene (III) was run over the same catalyst at 550-560°, without diluent, and with a feed rate of 0.3 hr^{-1}. Before experiment the system was blown with nitrogen. The yield of catalyzate was 87%, $n^{20}D$ 1.4975. The gas was analyzed chromatographically [8]. The analysis revealed a very high methane content of 39.2% in the gas, while the hydrogen content was 53.7%. The catalyzate from two experiments (18.6 g) was fractionally distilled.

1st fraction, b. p. 28-68° (25 mm), 2.15 g, $n^{20}D$ 1.4855, d^{20}_4 0.8078.

Found %: C 81.54, 81.74; H 9.78, 9.85; Si 5.70, 6.00, unsaturates 50.7 (strong odor of ethylbenzene).

2nd fraction, b. p. 69-100° (25 mm), 5.45 g, $n^{20}D$ 1.5003, d^{20}_4 0.822.

Found %: C 76.31, 76.26; H 9.88, 10.07; Si 11.6, 11.42; unsaturates 95.0.

3rd fraction, b. p. 102-106° (25 mm), 8.85 g, $n^{20}D$ 1.4995, d^{20}_4 0.8153.

Found %: C 80.22, 80.48; H 10.31, 10.49; Si 10.01, 9.86; unsaturates 97.6. $C_{11}H_{16}Si$. Calculated %: C 74.89; H 9.09; Si 15.93.

It is obvious that the dehydrogenation was accompanied by cracking reactions, mainly at the Si – C bond, which was responsible for the low amount of silicon in the reaction products.

Fractional distillation of the catalyzate and analysis of the gas,* obtained at 550-560°, also revealed that besides dehydrogenation the trimethylsilylethylbenzene suffered cleavage with the formation of ethylbenzene and other liquid and gaseous by-products, mainly methane. Our experiments with trimethylsilylethylbenzene continue.

The dehydrogenation of trichloroethylsilane (b. p. 97-98°, $n^{20}D$ 1.4230, d^{20}_4 1.15) was run on an oxide catalyst that had been prepared from a mixture of ferric and copper nitrates, and whose activity had been previously tested on ethylbenzene. The experiments were started at 574-579°, but at this temperature the trichloroethylsilane decomposed completely with the formation of gaseous products. Reducing the temperature of the experiments to 425-518° gave a liquid catalyzate containing a small amount of unsaturates (Table 2). The composition of the gas from some of the experiments is given in Table 3. The data in Tables 2 and 3 show that

TABLE 2

Dehydrogenation of Trichloroethylene (Catalyst Volume 25 ml)

Expt. No.	Expt. temp.	Reaction time (min)	Space velocity of addition (hr^{-1})	Amount of substance passed through (in g)	Amt. of catalyzate obtained		Amt. of gas collected (in liters)	Amt. of unsaturates in catalyzate (in %)
					g	%		
10	574—579°	60	0.2	6.0	0.0	0.0	1.17	—
11	425—430	60	0.224	6.5	3.5	53.8	0.225	7.9
12	518	120	0.24	13.8	10.0	72.4	0.588	4.1
13	428	90	0.18	12.5	10.3	82.5	—	5.4
14	450	255	0.144	17.6	5.5	88.1	0.179	4.4
15	440	75	0.42	15.1	5.0	33.0	0.38	6.7
16	435	165	0.21	21.9	13.0	59.3	0.944	6.7

TABLE 3

Analysis of Gaseous Reaction Products from the Dehydrogenation of Trichloroethylsilane (Volume %)

Expt. No.	H_2	CH_4	C_2H_4	C_2H_6
10	24.4	Not determined	9.6	Not determined
12	17.0	The same	5.6	The same
15	15.6	4.3	16.7	63.5
16	28.7	3.7	2.6	65.0

even at 425-430° (using the indicated catalyst) there is profound decomposition of the trichloroethylsilane molecule with the formation of ethane, ethylene, and methane. The amount of dehydrogenation proved to be very small. The yield of vinyltrichlorosilane was approximately the same as in its direct synthesis from vinyl chloride [10].

* Analysis of the gas by the chromatographic column technique was made by T. K. Lavrovskaya, for which we wish to thank her.

SUMMARY

1. It was shown that 1-ethylphenyl-2-methyldichlorosilylethane when passed over a mixed oxide catalyst at 490-500° is readily dehydrogenated to the corresponding silicon-containing styrene. In the case of trimethylsilylethylbenzene, together with dehydrogenation, substantial cleavage occurs.

2. It was shown that under the same conditions the dehydrogenation of trichloroethylsilane is only slight; here the main reaction is profound decomposition of the trichloroethylsilane with the formation of by-products.

LITERATURE CITED

[1] V. V. Korshak, A. M. Polyakova, A. A. Sakharova, A. D. Petrov, and E. A. Chernyshev, Doklady Akad. Nauk SSSR 119, 282 (1958).*

[2] A. D. Petrov, V. F. Mironov, and E. A. Chernyshev, Uspekhi Khim. 26, 292 (1957).

[3] B. N. Dolgov, G. V. Golodnikov, and N. E. Glushkova, Zhur. Obshchei Khim. 26, 1688 (1956).*

[4] B. N. Dolgov, G. V. Golodnikov, and K. G. Golodova, Doklady Akad. Nauk SSSR 117, 987 (1957).*

[5] A. A. Balandin, Zhur. Russ. Khim. Obshchestva 59, 909 (1929); A. A. Balandin, Uchenye Zapiski, Moskov. Gosudarst. Univ., 175, 97 (1956).

[6] A. A. Balandin, N. I. Shuikin, G. M. Marukyan, I. I. Brusov, R. G. Seimovich, T. K. Lavrovskaya, and V. K. Mikhailovskii, Zhur. Priklad. Khim. 32, 2566 (1959).*

[7] Roland P. Marquardt and E. N. Luce, Anal. Chem. 23, 629 (1951).

[8] H. Hrapia and H. Könnecke, J. pr. Chem. [4], 3, 106 (1956).

[9] K. W. Rosenmund and W. Kuhnhenn, Z. Untersuch. Nahr. Genussem. 46, 154 (1923).

[10] D. T. Hurd, J. Am. Chem. Soc. 67, 1545 (1945).

* Original Russian pagination. See C. B. translation.

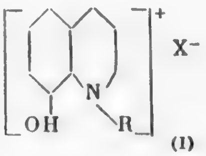
1-ALKYL-8-HYDROXYQUINOLINIUM SALTS

I. S. Ioffe and N. A. Selezneva

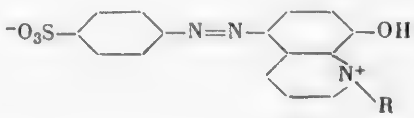
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 91-93, January, 1960.

Original article submitted January 9, 1959

Of the 1-alkyl-8-hydroxyquinolinium salts of general structure (I)

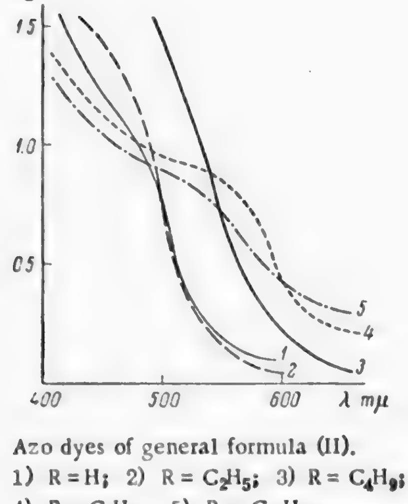


(I)



(II)

only the hydriodides of the N-methyl and N-ethyl derivatives have been described up to now [1-5]. To synthesize related compounds, containing alkyl radicals with longer carbon chains on the quaternary nitrogen atom, we reacted 8-hydroxyquinoline with some alkyl iodides and obtained the corresponding N-butyl-, N-octyl- and N-cetyl-8-hydroxyquinolinium hydriodides. For comparison, we also prepared the previously described 1-ethyl-8-hydroxyquinolinium iodide and the N-unsubstituted 8-hydroxyquinolinium hydriodide.



Azo dyes of general formula (II).
1) R = H; 2) R = C_2H_5; 3) R = C_4H_9; 4) R = C_8H_{17}; 5) R = $C_{16}H_{33}$.

In contrast to the N-ethyl and N-butyl derivatives, the higher homologs of the 1-alkyl-8-hydroxyquinolinium hydriodides are not precipitated by ether from their alcohol solutions. On dilution of the alcohol solutions with water these salts precipitate along with tarry impurities. For purification, we treated all of the salts with silver oxide, and the addition of the thus obtained hydroxides to an alcohol solution of picric acid gave the corresponding picrates, which crystallize readily from alcohol and have sharp melting points. The melting points decrease in regular fashion as the length of the carbon chain in the alkyl radical of the N-alkyl-8-hydroxyquinolinium salt increases. We also studied the behavior of the 1-alkyl-8-hydroxyquinolinium salts in the azo-coupling reaction. It proved that they, similar to the unsubstituted 8-hydroxyquinoline, react with diazo compounds without affecting the alkyl radical on the nitrogen.

Using sulfanilic acid as the diazo component, we synthesized some azo dyes of general structure (II). All of the dyes dissolve in alkali with a brown-red color and are precipitated on the addition of strong acid. The dyes were purified by recrystallization from dilute alcohol. They hardly change in color when the pH of the medium is varied. Visually, all of the dyes have a similar color, but as can be seen from a comparison of the absorption spectra of the dyes, increasing the length of the carbon chain in the alkyl radical on the nitrogen causes a definite bathochromic effect (Figure).

EXPERIMENTAL

1. 1-Alkyl-8-hydroxyquinolinium salts. Five grams of 8-hydroxyquinoline was heated with double the theoretical amount of the proper alkyl iodide in sealed tubes at 110-115° for 8 days. In the case of the N-ethyl- and N-butyl-8-hydroxyquinolinium iodides, after opening the tubes, the excess ethyl iodide and butyl iodide were distilled off, and the salts were purified by repeated solution in alcohol and precipitation with ether. 1-Ethyl-8-hydroxyquinolinium iodide was obtained as yellow crystals with m. p. 129-132°, and 1-butyl-8-hydroxyquinolinium iodide was obtained as dark yellow crystals with m. p. 162-164°. In the case of 1-octyl-8-hydroxyquinolinium iodide the contents of the ampul were poured into 50% alcohol, in which octyl iodide is insoluble. The salt was precipitated from the alcohol solution with water; the 1-octyl-8-hydroxyquinolinium iodide crystallized after long standing, but it had a very broad melting range of about 50°. In the case of hexadecyl-8-hydroxyquinolinium hydriodide we were unable to obtain the salt in a pure state, since the procedure of dissolving in alcohol and precipitation with water caused a partial precipitation of the cetyl iodide.

2. 1-Alkyl-8-hydroxyquinolinium picrates. All of the 1-alkyl-8-hydroxyquinolinium salts when treated with moist silver oxide gave the corresponding bases, which proved to be extremely hygroscopic and separated as garnet-red sticky masses, failing to crystallize even on long standing. The addition of picric acid solution to an alcohol solution of the base caused the corresponding picrate to separate, which were all purified by recrystallization from alcohol. The melting points of these picrates and the analysis results are given in Table 1.

TABLE 1

Picrate	Melting point	Found %: N	Empirical formula	Calculated %: N
1-Ethyl-8-hydroxyquinolinium	186°	13.75	$C_{17}H_{14}N_4O_8$	13.90
1-Butyl-8-hydroxyquinolinium	172	13.34	$C_{19}H_{18}N_4O_8$	13.00
1-Octyl-8-hydroxyquinolinium	138	11.23	$C_{23}H_{26}N_4O_8$	11.55
1-Hexadecyl-8-hydroxyquinolinium	112	9.70	$C_{31}H_{42}N_4O_4$	9.38

3. Azo dyes from 1-alkyl-8-hydroxyquinolinium salts. We took 0.01 mole each of the different N-alkyl-8-hydroxyquinolinium hydriodides as the azo components. The diazo solution was prepared from 0.01 mole of sulfanilic acid and 0.01 mole of sodium nitrite in acid medium. The azo coupling was run in the presence of 0.02 mole of alkali; here dark red solutions with a small amount of precipitate were obtained in all cases. The addition of hydrochloric acid gave a copious precipitate. The obtained dyes were recrystallized from dilute alcohol.

The analysis results for the azo dyes are given in Table 2.

TABLE 2

Azo dye of general formula (II) from:	Found %: N	Empirical formula	Calculated %: N
1-Ethyl-8-hydroxyquinolium	12.35	$C_{17}H_{15}N_3O_4S$	11.72
1-Butyl-8-hydroxyquinolinium	10.99	$C_{19}H_{19}N_3O_4S$	10.85
1-Octyl-8-hydroxyquinolinium	10.18	$C_{23}H_{27}N_3O_4S$	9.52
1-Hexadecyl-8-hydroxyquinolinium	7.04	$C_{31}H_{43}N_3O_4S$	7.58

SUMMARY

1. Condensation of 8-hydroxyquinoline with butyl iodide, octyl iodide and cetyl iodide gave the corresponding N-alkyl-8-hydroxyquinolinium salts, which were purified as the picrates.

2. The N-alkyl-8-hydroxyquinolinium hydroxides enter into the azo-coupling reaction, with retention of the alkyl radical on the nitrogen unchanged. Reaction of the bases with sulfanilic acid gave brown-red azo dyes, with a deepening of the color as the length of the carbon chain in the alkyl radical increased.

LITERATURE CITED

[1] A. Claus and H. Howitz, J. prakt. Chem. [2], 42, 226 (1890).

[2] A. Claus and H. Howitz, J. prakt. Chem. [2], 45, 256 (1892).

[3] A. Claus and H. Howitz, J. prakt. Chem. [2], 47, 426 (1893).

[4] A. Claus and E. Mohl, J. prakt. Chem. [2], 54, 7 (1896).

[5] E. Lippmann and F. Fleissner, Monatsh. 10, 668 (1889).

CATALYTIC ALKYLATION OF PHENOL WITH ISOPROPYL ALCOHOL

M. B. Turova-Polyak, N. V. Rudenko, and Ling Li-tang

Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 94-98, January, 1960

Original article submitted January 12, 1959

The alkylation of phenol in the vapor phase is discussed mainly in the patent literature [1-7]. Aliphatic alcohols and olefins serve as the alkylating agents, while acids deposited on carriers [1, 2], salts [1-4], and oxides [5-17] are used as catalysts. In many cases the reaction is run at elevated pressure. The oxide catalysts, Al_2O_3, $ThO_2 + Al_2O_3$, and gumbrin, are used in the alkylation of phenol with methyl and ethyl alcohols at 350-500° and atmospheric pressure; the yields of monoalkylphenols range from 52 to 70% [11-16]. When phenol was alkylated with isobutylene at 160° in the presence of aluminosilicate the yield of monobutylphenol was 10%, and that of diisobutylphenol was 48% [17]. The alkylation of phenol with propylene was run at 150-200° and elevated pressure in the presence of an oxide catalyst, containing aluminum oxide and silica. The yield of monoisopropylphenols was about 6%; along with isopropylphenol, a substantial amount of isopropyl phenyl ether was obtained [10].

The present paper is a continuation of our studies on the alkylation of benzene and its derivatives with isopropyl alcohol, and its purpose is to ascertain the effect exerted by the hydroxyl group on the alkylation reaction. The reaction was run on aluminosilicate catalyst in the vapor phase at atmospheric pressure. It was learned that high yields (about 95%) of monoisopropylphenol are obtained under these conditions, composed mainly of the p-isomer with some of the o-isomer as impurity. We were unable to detect either m-isopropylphenol or isopropyl phenyl ether in the reaction products.

The optimum conditions for running the reaction must be assumed to be a temperature of 210-230° and a space velocity of $0.2\ hr^{-1}$ for adding the reaction mixture. The composition of the reactant mixture exerts a great influence on the yield of isopropylphenols. Increasing the phenol concentration in the mixture to 20 moles per mole of alcohol favors a decrease in the yields of diisopropylphenols and an increase in the yields of monoisopropylphenols up to 81%. The yield of monoisopropylphenols rises to 95% when the unreacted phenol is reused. Increasing the alcohol concentration in the reaction mixture favors the formation of dialkyl products. It was established that the activity of the catalyst remains high for 19 hours, and then it drops sharply. The activity of the catalyst is restored completely by passing a strong stream of dry air through the apparatus for 2-2.5 hours at 500-550°. An increase in the yield of isopropylphenol (63.5%) when compared with the yield of isopropylbenzene (59%) is in agreement with the ability of orienting agents of the first kind to strongly increase the electron density of the ring, which explains the greater ease with which phenol enters into electrophilic substitution reactions.

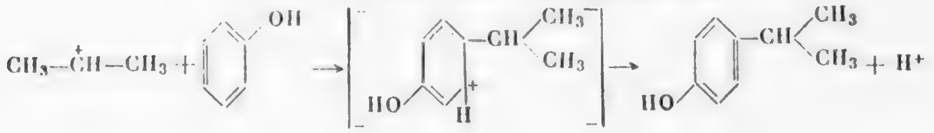
The mechanism for the alkylation of phenol by alcohols in the presence of acid catalysts, in particular, aluminosilicate catalysts, has not been elucidated conclusively. At the present time, the opinion exists [16, 12] that the intermediate stage in the alkylation of phenol by alcohols over aluminum oxide and gumbrin are phenol ethers, with their subsequent rearrangement to alkylphenols.

The results obtained by us do not permit the assumption that the alkylation of phenol with isopropyl alcohol under our conditions goes through the stage of forming isopropyl phenyl ether. This is based on the fact that neutral products (isopropyl phenyl ether) are absent in the catalyzates, and also because of the rapid rate with which isopropyl alcohol dehydrates to propylene.

The alkylation of benzene with olefins in the presence of acid catalysts is explained [18] by the formation of carbonium ions in the reaction process, which alkylate the benzene. We consider it possible to use the same mechanism in explaining the reaction investigated by us, similar to what was done earlier [19].

$$C_3H_7OH \rightarrow CH_2 = CH - CH_3$$

$$CH_2{=}CH{-}CH_3 + H^+ \ (\text{cat.}) \longrightarrow CH_3{-}\overset{+}{C}H{-}CH_3$$



EXPERIMENTAL

The reaction was run over commercial aluminosilicate bead catalyst under conditions similar to those described in a previous paper [20]. The starting materials, purified and distilled in advance, had constants corresponding to those given in the literature. The alkylation products, the monoisopropylphenol fraction, was collected in the interval 200-231°, since according to the literature the boiling point of o-isopropylphenol is 204 and 214.5° (760 mm); m. p. 16°, $n^{20}D$ 1.5310, d^{20}_4 1.0140 [21, 22]; that of p-isopropylphenol is 228.2° (760 mm); m. p. 61°, $n^{20}D$ 1.5228, d^{20}_4 0.9824 [21, 24, 25]; and that of m-isopropylphenol is 228° (760 mm); m. p. 26°, d^{25}_4 0.9929 [21, 26, 13]. The yield of alkylation products was based on the alcohol taken for reaction.

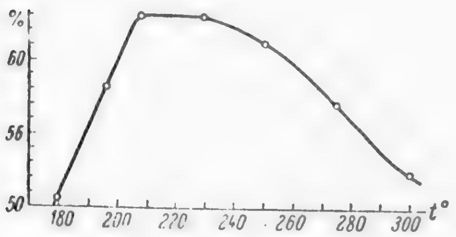


Fig. 1. Dependence of the yields of monoisopropylphenols on the reaction temperature. Space velocity 0.2 hr^{-1}; phenol : alcohol ratio = 6 : 1.

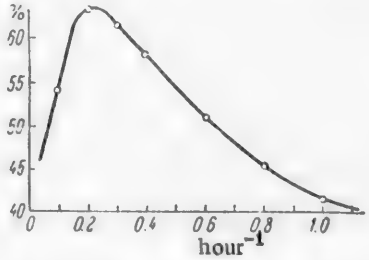


Fig. 2. Dependence of the yields of monoisopropylphenols on the space velocity of adding the reactant mixture. Phenol : alcohol ratio = 6 : 1; 210°.

The effect of temperature on the yield of isopropylphenol was investigated at a phenol : alcohol ratio of 6 : 1* and a space velocity of 0.2 hr^{-1} for adding the reactant mixture (Fig. 1).

Effect of the rate of addition of the reactant mixture. The experiments were run at 210° using a mixture with the above indicated composition; the space velocity was varied from 0.1 to 1 hr^{-1} (Fig. 2).

Effect of the composition of the starting mixture. The experiments were run at 210° and a space velocity of 0.2 hr^{-1} for adding the reactant mixture. The mole ratio of the reaction components in one series of experiments was varied from 2 to 20 moles of phenol per mole of alcohol. In some of the experiments we used pure phenol (I), while in other experiments we used the unreacted phenol (II) recovered from previous experiments (the fraction boiling at 170-200°); this fraction, based on the data of our earlier papers [20], contains propylene polymers, boiling up to 200°, and functioning as peculiar catalysts for the indicated reaction. In another series of experiments the ratio of the components was varied from 1 to 20 moles of alcohol per mole of phenol (Figs. 3-5).

* We took a ratio of 6 : 1 in order to be able to compare the results obtained in the present investigation with those obtained in previous papers [20, 27].

The active life of the catalyst was studied for a period of 25 hours at a phenol : alcohol ratio of 6 : 1, a temperature of 210°, and a space velocity of 0.2 hr^{-1}. From Fig. 6 it can be seen that the activity of the catalyst increases in the first three hours and reaches a maximum during the 4-5th hour of operation (the yield of isopropylphenols reaches 75%), after which it drops somewhat and remains constant (65%) for another 14 hours. After 19 hours of operation the activity of the catalyst drops sharply.

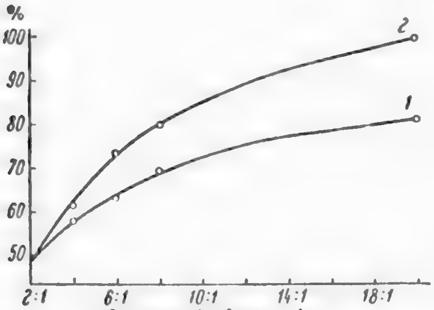


Fig. 3. Relation between the yields of monoisopropylphenols and the ratio of the components in the phenol : alcohol mixture at 210° and a space velocity of 0.2 hr^{-1}. 1) Pure phenol; 2) unreacted phenol.

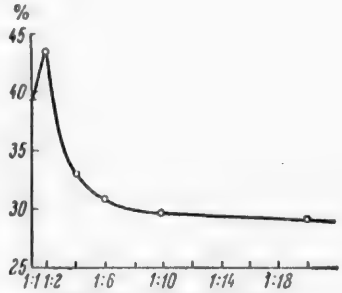


Fig. 4. Relation between the yields of monoisopropylphenols and the ratio of the components in the phenol : alcohol mixture.

To isolate the pure isopropylphenols we subjected the alkylation products to a careful fractional distillation. Here the following fractions were collected in all of the experiments: 1st, 170-200°, 2nd, 200-231°, being the main fraction of monoisopropylphenols, and 3rd, above 231°, containing the diisopropylphenols. The 2nd fraction dissolved completely in 10% NaOH solution, which indicates that it does not contain isopropyl phenyl ether. After suitable treatment, this fraction was distilled at 41 mm through a column filled with glass packing and having an efficiency of 40 theoretical plates.

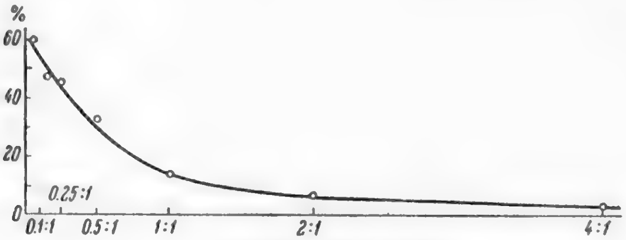


Fig. 5. Relation between the yields of diisopropylphenols and the ratio of the components in the phenol : alcohol mixture.

From the distillation curve for the monoisopropylphenol fraction (Fig. 7) it follows that the fraction with b. p. 124-124.3°, m. p. 15.5°, $n^{20}D$ 1.5282, and d^{20}_4 0.9963, is o-isopropylphenol. Reaction of this fraction with monochloroacetic acid [32] gave o-isopropylphenoxyacetic acid with m. p. 131.5-132.5°. The melting point given by I. P. Tsukervanik [23] for o-isopropylphenoxyacetic acid is 129-130°. Reaction with potassium persulfate* [28] gave a blue solution, which is characteristic for o-isopropylphenol.

Freezing the 124.3-136.8° fraction, $n^{20}D$ 1.5271, and d^{20}_4 0.9958, gave o-isopropylphenol with $n^{20}D$ 1.5280 and d^{20}_4 0.9966, and a small amount of p-isopropylphenol with m. p. 60°. From the 136.8-137.3° fraction on cooling we isolated some crystals of p-isopropylphenol, melting at 60° after recrystallization from dilute alcohol; the literature [23, 29] m. p. is 61°. Reaction of the obtained p-isopropylphenol with mono-

chloroacetic acid [30] gave p-isopropylphenoxyacetic acid with m. p. 81.5-82.3°; literature data [23, 30]: m. p. 80-81°. Reaction with benzoyl chloride gave the benzoate [33] with m. p. 71.2-72.2°; literature data [23, 30]: m. p. 70-71°. Reaction of p-isopropylphenol with potassium persulfate in alkaline solution gave an orange solution, which is characteristic for p-isopropylphenol [28].

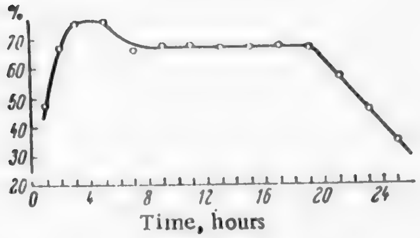


Fig. 6. Relation between the yields of monoisopropylphenols and the active life of the catalyst without its regeneration. Temperature 210°; space velocity 0.2 hr^{-1}; phenol : alcohol ratio = 6 : 1.

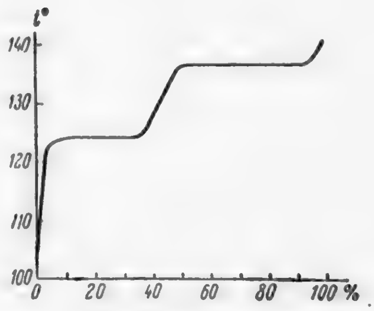


Fig. 7. Curve for the distillation of the monoisopropylphenol fraction through the column.

From the fractions, boiling above 231° in the first distillation, we isolated 2,4-diisopropylphenol with b. p. 144.5-145.6° (20 mm), $n^{25}D$ 1.5120 and d^{25}_4 0.9466, by distillation through the column.

Found %: C 80.67, 80.80; H 10.52, 10.60. $C_{12}H_{18}O$. Calculated %: C 80.89; H 10.11.

Literature data: [31]: b. p. 97° (2 mm), $n^{25}D$ 1.5122, d^{25}_4 0.9474.

SUMMARY

It was established that it is possible to obtain isopropylphenols (mainly the p-isomer) in up to 95% yield by the alkylation of phenol with isopropyl alcohol on an aluminosilicate catalyst at atmospheric pressure, a temperature of 210-230°, and a space velocity of 0.2 hr^{-1} for the addition of the reactants.

LITERATURE CITED

[1] Nobuto Ohta, J. Chem. Soc. Japan, Ind. Chem. Sect. 51, 141 (1948).

[2] Nobuto Ohta, ibid. p. 143.

[3] U. S. Patent 2,442,878 (1948); Chem. Abstr. 42, 6848 g (1948).

[4] Dutch Patent 64,991 (1949); Chem. Abstr. 44, 5908d (1950).

[5] British Patent 308,662 (1928); Chem. Abstr. 24, 378 (1930).

[6] U. S. Patent, 2,684,389 (1954); Chem. Abstr. 49, 11010a (1955).

[7] U. S. Patent 2,678,951 (1954); Chem. Abstr. 49, 4715g (1955).

[8] U. S. Patent 2,448,942 (1948); Chem. Abstr. 43, 687d (1949).

[9] U. S. Patent 2,514,419 (1950); Chem. Abstr. 44, 8949h (1950).

[10] U. S. Patent 2,430,190 (1937); Chem. Abstr. 42, 1319f (1948).

[11] British Patent 602,257 (1948); Chem. Abstr. 42, 8212f (1948).

[12] I. N. Samsonova and L. I. Khotyntseva, Zhur. Obshchei Khim. 27, 3189 (1957).*

[13] I. N. Samsonova, Zhur. Obshchei Khim. 27, 2697 (1957).*

[14] Z. P. Aleksandrova, Zhur. Obshchei Khim. 12, 522 (1942).

[15] C. Hansch and D. Robertson, J. Am. Chem. Soc. 72, 4810 (1950).

[16] N. Cullinane and S. Chard, J. Chem. Soc. 821 (1945).

[17] U. S. Patent 2,578,597 (1951); Chem. Abstr. 46, 7120h (1952).

[18] C. Price, Chem. Revs. 29, 37 (1941).

[19] V. I. Isagulyants and V. N. Tishkova, Transactions of the All-Union Convention on the Complex Chemistry and Processing of Petroleum Gases [In Russian] (Acad. Sci. USSR Press, 1956), p. 464.

[20] M. B. Turova-Polyak, N. V. Danilova, and N. V. Kuklina, Zhur. Obshchei Khim. 26, 1936 (1956).*

[21] T. Jordan, Vapor pressure of organic compounds (New York, 1954).

[22] F. J. Sowa, H. D. Hinton, and J. A. Nieuwland, J. Am. Chem. Soc. 54, 3694 (1932).

[23] I. Tsukervanik and V. Tambovtseva, Zhur. Obshchei Khim. 25, 820 (1955).*

[24] F. J. Sowa, G. F. Hennion, and J. A. Nieuwland, J. Am. Chem. Soc. 57, 709 (1935).

[25] R. Smith, J. Am. Chem. Soc. 56, 717 (1934).

[26] F. J. Sowa, H. D. Hinton, and J. A. Nieuwland, J. Am. Chem. Soc. 55, 3406 (1933).

[27] M. B. Turova-Polyak, N. V. Rudenko, and I. L. Parbuzina, Zhur. Obshchei Khim. 29, 3243 (1959).*

[28] S. Soloway and A. Santoro, Anal. Chem. 27, 798 (1955).

[29] J. Niederl and E. Storch, J. Am. Chem. Soc. 55, 293 (1933).

[30] I. Tsukervanik and Z. Nazarova, Zhur. Obshchei Khim. 7, 623 (1937).

[31] M. Carpenter, W. Easter, and T. Wood, J. Org. Chem. 16, 615 (1951).

[32] N. M. Karavaev, N. N. Bashkirov, and L. P. Kraeva, Khim. Tverdogo Topliva 4, 585 (1933).

[33] F. Blicke and O. Weinkauff, J. Am. Chem. Soc. 54, 331 (1932).

* Original Russian pagination. See C. B. translation.

CHEMISTRY OF SELENOPHENE

XXIV.* CONDENSATION OF 5-NITROSELENOPHENE-2-CARBOXALDEHYDE AND β-(5-NITRO-2-SELENIENYL)ACROLEIN WITH HYDRAZINE DERIVATIVES

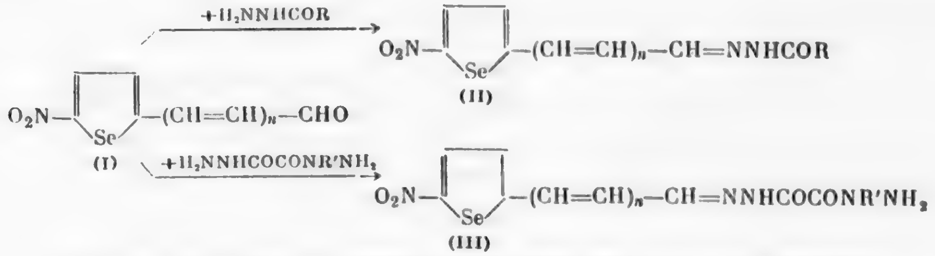
Yu. K. Yur'ev and E. L. Zaitseva

Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 98-101, January, 1960

Original article submitted January 5, 1959

In this paper 5-nitroselenophene-2-carboxaldehyde [1] and β-(5-nitro-2-selenienyl)acrolein [2] (I) were condensed with various hydrazine derivatives to yield 5-nitro-2-selenienylideneamines and β-(5-nitro-2-selenienyl)allylideneimines, respectively. Condensation with the hydrazides of cyanoacetic, furoic and isonicotinic acids gave the corresponding acylhydrazones of these aldehydes (II). Reaction of 5-nitroselenophene-2-carboxaldehyde with semioxamazide and 5-(β-hydroxyethyl)semioxamazide gave the corresponding semioxamazones (III).

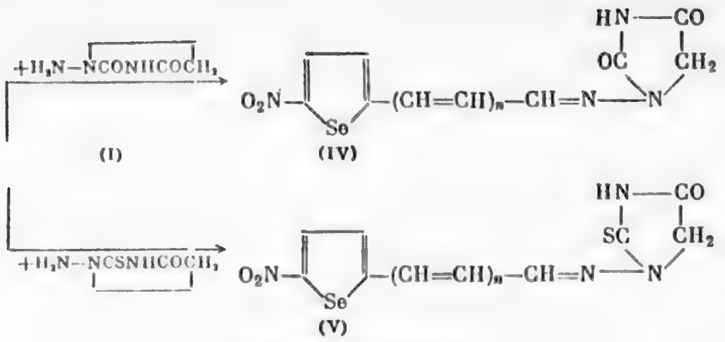


(I $n = 0$ & 1); (II $n = 0$ & 1; R = CH_2CN, C_4H_3O, C_5H_4N); (III $n = 0$; R' = H, CH_2CH_2OH).

The condensation with 1-aminohydantoin was run by the Uota and Takai method [3, 4], described for the corresponding condensation of 5-nitro-2-furaldehyde and β-(5-nitro-2-furfuryl)acrolein. The aminohydantoin, formed by the reaction of ethyl hydrazineacetate with potassium cyanate and subsequent hydrolysis of the ethyl aminohydantoate with dilute sulfuric acid, was reacted directly with 5-nitroselenophene-2-carboxaldehyde and β-(5-nitro-2-selenienyl)acrolein, without prior isolation and purification; this made it possible to obtain 1-(5-nitro-2-selenienylidene)aminohydantoin (IV) and 1-[β-(5-nitro-2-selenienyl)allylidene]aminohydantoin (IV) in high yields.

Condensation with 1-amino-2-thiohydantoin led to 1-(5-nitro-2-selenienylidene)amino-2-thiohydantoin (V) and 1-[β-(5-nitro-2-selenienyl)allylidene]amino-2-thiohydantoin (V), respectively.

* Communication XXIII was published in the journal "Optika i Spektroskopiya" 6, 45 (1959).



I, IV, and V: n = 0 and 1

EXPERIMENTAL

a) 4-Phenylsemicarbazone of 5-nitroselenophene-2-carboxaldehyde. A mixture of 0.51 g of 5-nitroselenophene-2-carboxaldehyde in 7 ml of alcohol and 0.47 g of 4-phenylsemicarbazide in 1.5 ml of water was heated for 5 minutes on the water bath, cooled, and treated with 10 ml of water. The precipitate was filtered and washed with water. We obtained 0.78 g (93.5%) of product. Yellow crystals, m. p. 231-233° (with decomp., from alcohol).

Found %: C 42.43, 42.34; H 3.07, 3.05; Se 23.52, 23.36. $C_{12}H_{10}O_3N_4Se$. Calculated %: C 42.74; H 2.99; Se 23.42.

4-Phenylsemicarbazone of β-(5-nitro-2-selenienyl)acrolein. Using method "a" we obtained 0.82 g (92%) of product from 0.57 g of β-(5-nitro-2-selenienyl)acrolein in 12 ml of alcohol and 0.47 g of 4-phenylsemicarbazide hydrochloride in 1.5 ml of water. Orange crystals, m. p. 209-210° (with decomp. from alcohol).

Found %: C 45.89, 45.95; H 3.16, 3.26; Se 21.50, 21.40. $C_{14}H_{12}O_3N_4Se$. Calculated %: C 46.29; H 2.90; Se 21.74.

b) 1-(5-Nitro-2-selenienylidene)-2-cyanoacetylhydrazone. A solution of 0.51 g of 5-nitroselenophene-2-carboxaldehyde in 8 ml of alcohol was added dropwise with stirring to a solution of 0.25 g of cyanoacetic acid hydrazide in 7 ml of water, acidified with 1 ml of concentrated hydrochloric acid. Then the mixture was allowed to stand for 3 hours at 20°, after which the precipitate was filtered and washed with water and small amounts of alcohol and ether. We obtained 0.66 g (93%) of yellow crystals, m. p. 241-242° (with decomp., from alcohol).

Found %: C 33.59, 33.60; H 2.36, 2.47; Se 27.92, 27.82. $C_8H_6O_3N_4Se$. Calculated %: C 33.71; H 2.12; Se 27.70.

1-(5-Nitro-2-selenienylidene)-2-(2-furoyl)hydrazone. Using method "b" we obtained 0.72 g (≈ 100%) of product from 0.51 g of 5-nitroselenophene-2-carboxaldehyde and 0.32 g of furoylhydrazide. Lemon yellow crystals, m. p. 266-267° (with decomp., from alcohol).

Found %: C 38.51, 38.59; H 2.49, 2.55; Se 25.04, 25.12. $C_{10}H_7O_4N_3Se$. Calculated %: C 38.47; H 2.26; Se 25.29.

1-(5-Nitro-2-selenienylidene)semioxamazone. Using method "b" we obtained 0.76 g (≈ 100%) of product from 0.51 g of 5-nitroselenophene-2-carboxaldehyde and 0.29 g of semioxamazide. Yellow crystals, m. p. 252-253° (with decomp., from alcohol).

Found %: C 27.95, 27.99; H 2.27, 2.38; Se 25.77, 25.68. $C_7H_7O_4N_5Se$. Calculated %: C 27.65; H 2.32; Se 25.97.

1-(5-Nitro-2-selenienylidene)-5-(β-hydroxyethyl)semioxamazone. Using method "b", we obtained 0.78 g (90%) of product from 0.51 g of 5-nitroselenophene-2-carboxaldehyde and 0.41 g of 5-(β-hydroxyethyl)-semioxamazide. Yellow crystals, m. p. 251-252° (with decomp., from alcohol).

Found %: C 31.30, 31.40; H 3.30, 3.26; Se 22.37, 22.44. $C_9H_{11}O_5N_5Se$. Calculated %: C 31.05; H 3.18; Se 22.67.

1-[β-(5-Nitro-2-selenienyl)allylidene]-2-cyanoacetylhydrazone. Using method "b", we obtained 0.77 g (≈100%) of product from 0.57 g of β-(5-nitro-2-selenienyl)acrolein in 12 ml of alcohol and 0.25 g of cyanoacetic acid hydrazide in 7 ml of water. Orange crystals, m. p. 219-221° (with decomp., from alcohol).

Found %: C 38.77, 38.67; H 2.86, 2.73; Se 25.17, 25.10. $C_{10}H_8O_3N_4Se$. Calculated %: C 38.60; H 2.59; Se 25.37.

1-[β-(5-Nitro-2-selenienyl)allylidene]-2-(2-furoyl)hydrazone. Using method "b" we obtained 0.81 g (96%) of product from 0.57 g of β-(5-nitro-2-selenienyl)acrolein in 12 ml of alcohol and 0.32 g of furoylhydrazide in 7 ml of water. Orange crystals, m. p. 225-227° (with decomp., from alcohol).

Found %: C 42.44, 42.46; H 2.79, 2.81; Se 23.15, 23.20. $C_{12}H_9O_4N_3Se$. Calculated %: C 42.62; H 2.68; Se 23.35.

c) 1-(5-Nitro-2-selenienylidene)-2-isonicotinoylhydrazone. A mixture of 0.51 g of 5-nitroselenophene-2-carboxaldehyde in 7 ml of alcohol and 0.34 g of isonicotinoylhydrazide in 6 ml of water was refluxed for several minutes, cooled, treated with 10 ml of water, and the precipitate filtered and washed with water. We obtained 0.74 g (91%) of yellow crystals, m. p. 243-244° (with decomp., from alcohol).

Found %: C 40.87, 40.91; H 2.82, 2.80; Se 22.98, 23.12. $C_{11}H_8O_3N_4Se$. Calculated %: C 40.87; H 2.49; Se 23.14.

1-[β-(5-Nitro-2-selenienyl)allylidene]-2-isonicotinoylhydrazone. Using method "c" we obtained 0.78 g (94%) of product from 0.57 g of β-(5-nitro-2-selenienyl)acrolein in 12 ml of alcohol and 0.34 g of isonicotinoylhydrazide in 6 ml of water. Orange crystals, m. p. 244-245° (with decomp., from alcohol).

Found %: C 44.77, 44.75; H 3.10, 3.13; Se 22.41, 22.48. $C_{13}H_{10}O_3N_4Se$. Calculated %: C 44.71; H 2.89; Se 22.61.

d) 1-(5-Nitro-2-selenienylidene)aminohydantoin. A mixture of 1 g (0.006 mole) of ethyl hydrazineacetate hydrochloride and 1.5 g (0.018 mole) of potassium cyanate was dissolved in 5 ml of water and the solution allowed to stand at 20° for 12 hours. Then 25 ml of 2 N sulfuric acid solution was added, the mixture refluxed for 2 hours, then evaporated on the water bath to a volume of 15 ml, cooled, and then treated with 0.7 g (0.0034 mole) of 5-nitroselenophene-2-carboxaldehyde in 7 ml of alcohol. A copious, finely crystalline precipitate deposited immediately; after 4 hours the precipitate was filtered, and washed with water and small amounts of alcohol and ether. We obtained 0.83 g (81.5%) of yellow crystals, m. p. 263-264° (with decomp., from alcohol).

Found %: C 31.76, 31.78; H 2.04, 1.90; Se 26.32, 26.39. $C_8H_6O_4N_4Se$. Calculated %: C 31.92; H 2.01; Se 26.22.

1-[β-(5-Nitro-2-selenienyl)allylidene]aminohydantoin. Using method "d", we obtained 0.74 g (84%) of product from 0.62 g of β-(5-nitro-2-selenienyl)acrolein in 15 ml of alcohol, 1 g (0.006 mole) of ethyl hydrazineacetate hydrochloride and 1.5 g (0.018 mole) of potassium cyanate in 5 ml of water. Red crystals, m. p. 262-264° (with decomp., from alcohol).

Found %: C 36.81, 36.69; H 2.74, 2.59; Se 23.90, 23.98. $C_{10}H_8O_4N_4Se$. Calculated %: C 36.71; H 2.47; Se 24.13.

e) 1-(5-Nitro-2-selenienylidene)amino-2-thiohydantoin. A solution of 0.33 g of 1-amino-2-thiohydantoin in 2.5 ml of water was prepared by heating, after which 0.51 g of 5-nitroselenophene-2-carboxaldehyde in 4 ml of alcohol was added, the mixture refluxed for 5 minutes, then cooled, and the precipitate was filtered and washed with water and with small amounts of alcohol and ether. We obtained 0.8 g (95%) of yellow-orange crystals, m. p. 248-250° (with decomp., from alcohol).

Found %: C 30.10, 29.92; H 1.85, 1.84. $C_8H_6O_3N_4SSe$. Calculated %: C 30.28; H 1.91.

1-[β-(5-Nitro-2-selenienyl)allylidene]amino-2-thiohydantoin. Using method "e" we obtained 0.78 g (93%) of product from 0.57 g of β-(5-nitro-2-selenienyl)acrolein in 12 ml of alcohol and 0.33 g of 1-amino-2-thiohydantoin in 2.5 ml of water. Red crystals, m. p. 265-267° (with decomp., from acetone).

Found %: C 34.81, 34.83; H 2.45, 2.52. $C_{10}H_8O_3N_4SSe$. Calculated %: C 34.99; H 2.35.

SUMMARY

The condensation of 5-nitroselenophene-2-carboxaldehyde and β-(5-nitro-2-selenienyl)acrolein with hydrazides gave the following new compounds of the selenophene series: 1-(5-nitro-2-selenienylidene)- and 1-[β-(5-nitro-2-selenienyl)allylidene]-2-(2-furoyl)hydrazone, 1-(5-nitro-2-selenienylidene)- and 1-[β-(5-nitro-2-selenienyl)allylidene]-2-cyanoacetylhydrazone, 1-(5-nitro-2-selenienylidene)- and 1-[β-(5-nitro-2-selenienyl)allylidene]-2-isonicotinoylhydrazone, and also 1-(5-nitro-2-selenienylidene)semioxamazone and 1-(5-nitro-2-selenienylidene)-5-(β-hydroxyethyl)semioxamazone.

The condensation of 5-nitroselenophene-2-carboxaldehyde and β-(5-nitro-2-selenienyl)acrolein with 1-aminohydantoin and 1-amino-2-thiohydantoin led to obtaining the previously unknown 1-(5-nitro-2-selenienylidene)aminohydantoin, 1-[β-(5-nitro-2-selenienyl)allylidene]aminohydantoin, 1-(5-nitro-2-selenienylidene)amino-2-thiohydantoin and 1-[β-(5-nitro-2-selenienyl)allylidene]amino-2-thiohydantoin, respectively.

LITERATURE CITED

[1] Yu. K. Yur'ev and E. L. Zaitseva, Zhur. Obshchei Khim. 28, 2165 (1958).*

[2] Yu. K. Yur'ev and E. L. Zaitseva, Zhur. Obshchei Khim. 29, 1965 (1959).*

[3] H. Uota and A. Takai, J. Pharm. Soc. Japan 75, 117 (1955); Referat. Zhur. Khim. (1956), 78, 136.

[4] Japanese Patent 1731; Chem. Abstr. 51, 3668 (1957).

* Original Russian pagination. See C. B. translation.

SYNTHESIS OF SOME (β-CHLOROETHYL)AMINO DERIVATIVES OF THIOPHENE

Ya. L. Gol'dfarb and M. S. Kondakova

Institute of Organic Chemistry, Academy of Sciences of the USSR

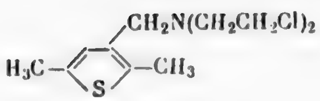
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 102-107, January, 1960

Original article submitted November 20, 1958

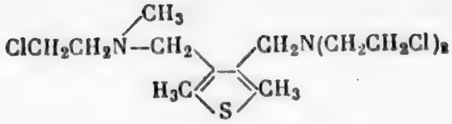
As is known, studies on the synthesis of compounds bearing the β-chloroethylamino grouping of atoms, and their testing as antitumor agents, have found wide expansion in the last decade. The prototype of such derivatives is methylbis(β-chloroethyl)amine (embichine, duamin, HN_2), described as early as 1935 by Prelog and Stepan [1]. Since then a large number of similar amines have been prepared, belonging to the class of so-called nitrogen amines have been prepared, belonging to the class of so-called nitrogen mustards, in particular, aryl(β-chloroethyl)amines, studied in detail by Ross [2], who investigated their chemical behavior and antitumor activity. A large number of papers are also devoted to the synthesis and testing of β-chloroethylamino derivatives of heterocyclic compounds, for example, those containing the pyrimidine [3], pyridine [4, 14], thiazole [5], benzimidazole [6], quinoline, and acridine [7] ring. Some of these compounds show a well defined ability to inhibit the growth of tumors and leukoses in experimental animals [8]. A characteristic property of the discussed type of compounds is their great toxicity, which is one of the reasons it is difficult to find compounds among them with the desired complex of properties. Nevertheless, interest in this group of compounds is retained, as is evidenced by the chemical and medical literature on the matter.

In a recent paper [9] we described the transformations of 3-chloromethyl- and 3,4-bis(chloromethyl)-2,5 dimethylthiophene, testifying to the high reactivity shown by these compounds. It seemed appropriate to also use them in the synthesis of β-chloroethylamino derivatives. In support of this were the results obtained in studying the antitumor activity and relative toxicity of benzylbis(β-chloroethyl)amine derivatives [10], i.e., compounds containing a grouping of atoms (benzyl) analogous to the thenyl group, and also some data dealing with the pharmacological properties of thiophene derivatives; specifically, it was shown that the latter with a functional grouping in the β-position of the nucleus are more effective than are the isomeric α-substituted compounds. In this connection, it is interesting to mention that, judging from the still extremely limited data [11, 12], β-3-thienylalanine was tested as an agent for the control of malignant tumors, as well as β-2-thienylalanine [13]. Finally, reference should be made to the general conclusion arrived at by Acheson and co-workers [14], in essence reducing to the fact that replacing the benzene ring in physiologically active compounds by the thiophene ring at times leads to an increase in the activity.

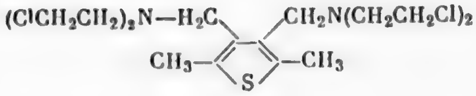
To obtain β-chloroethylamino derivatives from the mentioned chloromethyl derivatives of thiophene we made use of known methods to convert the chloromethyl function to the diethylaminoethanol grouping, with subsequent replacement of the hydroxyl group by chlorine [4]. Since it is possible to obtain only mediocre yields using this route, we made a parallel study of another approach, namely, reaction of the chloromethyl derivatives with bis(β-chloroethyl)amine [15]. The compounds obtained in this manner as the hydrochlorides are depicted by formulas (I), (II), and (III):



(I)



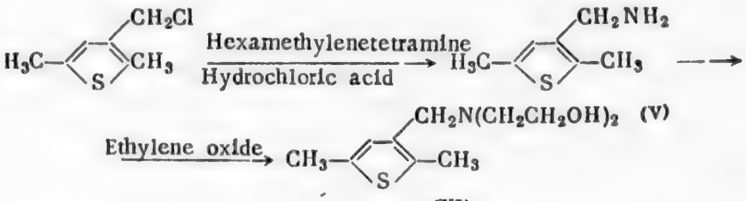
(II)



(III)

(IV)

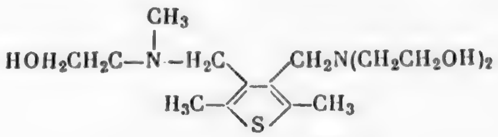
Aminoalcohol (VI), corresponding to (I), was synthesized by heating 3-chloromethyl-2,5-dimethylthiophene with diethanolamine. Although the compound distilled over quite a wide range, still its analysis results were in complete agreement with the calculated data. The other method of obtaining this compound, described below, is illustrated by the following scheme:



(V)

(VI)

The starting base for the synthesis of chloroethylamino derivative (II) – aminoalcohol (VII) – was obtained by reacting ethylene oxide with the 3-aminomethyl-4-methylaminomethyl-2,5-dimethylthiophene described by us earlier [9].



(VII)

In order to be able to determine the effect of shifting the bis(β-chloroethyl)aminomethyl group from the α to the β position of the thiophene nucleus on the physiological action, we synthesized* compound (IV), obtained earlier in low (12%) yield by Wilson and Tishler from 2-thenoyl chloride. On repeating the experiment of these investigators we were at first unable to obtain the crystalline hydrochloride of (IV); this was finally achieved by purifying the product through the picrate. The bis(β-hydroxyethyl)-2-thenylamine (VIII)

(VIII)

* This portion of the work was done by M. B. Ibragimova.

needed for the reaction was not obtained from thenoyl chloride, but instead it was obtained by the Leuckart method [17], by heating a mixture of 2-thiophenecarboxaldehyde, diethanolamine and formic acid.

The toxicity and antitumor activity of the mentioned chloroethylamino derivatives of thiophene were investigated by Pan' Ch'i-ts'ao in the Laboratory of Experimental Chemotherapy of the Institute of Experimental Pathology and Therapy of Cancer of the Academy of Medical Sciences of the USSR. All of the compounds proved to be quite toxic, * in which connection the toxicity of compound (IV), with the chloroethylamino function in the α position, exceeded that of the β-chloroethylamines described here. Their antitumor action was investigated relative to sarcoma "45" on rats and Ehrlich tumors on mice. Here it was found that their inhibition of tumor growth was slight. The authors wish to thank Pan' Ch'i-ts'ao for testing the described compounds.

EXPERIMENTAL

3-Aminomethyl-2,5-dimethylthiophene (V). A mixture of 30.4 g of the quaternary salt, prepared in conventional manner from 17 g of hexamethylenetetramine and 18 g of 2,5-dimethyl-3-thenoyl chloride [16], with 200 ml of alcohol and 35 ml of concentrated hydrochloric acid was heated on the water bath for 6 hours. The alcohol was vacuum-distilled; the residue was dissolved in 225 ml of water, and the solution was made alkaline with 40% KOH solution. The oil that separated here was extracted with ether; toward the end of the extraction the aqueous solution was saturated with potassium carbonate. After drying the extract over potassium carbonate the ether was distilled off, and the residue was vacuum-distilled. We obtained 9.3 g (60%) of 3-aminomethyl-2,5-dimethylthiophene.

B. p. 100° (12 mm).

Found %: C 59.52, 59.33; H 7.64, 7.82; S 22.66, 22.59; N 10.26, 9.96. $C_7H_{11}NS$. Calculated %: C 59.53; H 7.85; S 22.74; N 9.92.

The picrate after recrystallization from alcohol melted at 201°.

Found %: N 14.99, 14.83. $C_7H_{11}NS \cdot C_6H_2(OH)(NO_2)_3$. Calculated %: N 15.13.

3-Bis(β-hydroxyethyl)aminomethyl-2,5-dimethylthiophene (VI). a) Reaction of diethanolamine with 2,5-dimethyl-3-thenoyl chloride. A mixture of 8.2 g (0.05 mole) of 2,5-dimethyl-3-thenoyl chloride [16] and 8 g (0.05 mole) of diethanolamine in a small amount of a benzene-ether mixture was heated on the water bath for 4 hours, after which the solvents were vacuum-distilled. The oily residue was treated with water and 40% KOH solution. The product was extracted with ether and benzene; the combined extract was dried over magnesium sulfate. The residue from distilling off the solvents was vacuum-distilled. The following fractions were obtained at 3.5 mm: 1st, 94-167° (small amount); 2nd, 167-197°, 3.5 g; 3rd, 197-210°, 2.3 g.

Redistillation of the 2nd fraction gave 3-bis(β-hydroxyethyl)aminomethyl-2,5-dimethylthiophene with b. p. 184-197° (6 mm).

Found %: C 57.89, 57.89; H 8.34, 8.28; S 13.96, 14.09; N 5.94, 5.89. $C_{11}H_{19}O_2NS$. Calculated %: C 57.61; H 8.35; S 13.98; N 6.11.

b) Reaction of ethylene oxide with 3-aminomethyl-2,5-dimethylthiophene. To a solution of 17.7 g (0.12 mole) of 3-aminomethyl-2,5-dimethylthiophene in 60 ml of methyl alcohol, cooled in an ice-salt mixture, was added 30 ml of ethylene oxide. The mixture was kept for 2 days in the refrigerator and then for 24 hours at room temperature, after which the alcohol was distilled off. The residual colorless oil (35 g) was vacuum-distilled; the following fractions were isolated: 1st, 100° (13 mm), 2.4 g (starting amine); 2nd, 179-190° (6 mm), 16.7 g; 3rd, 190-210° (3 mm), 4.5 g; 4th, 210-230° (3 mm), 3.8 g; 5th, 230-250° (3 mm), 1.0 g.

The 2nd fraction contained 3-bis(β-hydroxyethyl)methylamino-2,5-dimethylthiophene.

3-Bis(β-chloroethyl)aminomethyl-2,5-dimethylthiophene (I) hydrochloride. a) Reaction of thionyl chloride with 3-bis(β-hydroxyethyl)aminomethyl-2,5-dimethylthiophene. To a solution of 1.5 g (0.007 mole) of 3-bis(β-hydroxyethyl)aminomethyl-2,5-dimethylthiophene in 10 ml of dry chloroform, cooled in ice, was

* However, many times less toxic than embichine.

gradually added a solution of 2 g (0.017 mole) of thionyl chloride in 5 ml of chloroform. The mixture was heated on the water bath for 1.5 hours. After distilling off the chloroform and excess thionyl chloride, the residue was treated with water; the solid reaction product was filtered rapidly and then purified by the technique of dissolving in absolute alcohol and precipitating with ether. We obtained 0.64 g of a crystalline substance, which after a double reprecipitation with ether from acetone solution melted at 171-172°.

Found %: C 43.50, 43.55; H 5.89, 5.84. $C_{11}H_{18}NCl_3S$. Calculated %: C 43.64; H 5.99.

The picrate was obtained by mixing an acetone solution of the free base with an alcohol solution of picric acid. After recrystallization from alcohol, m. p. 101-105° (decomp.).

Found %: N 10.61, 10.85. $C_{11}H_{17}NCl_2S \cdot C_6H_2(OH)(NO_2)_3 \cdot H_2O$. Calculated %: N 10.91.

b) Reaction of bis(β-chloroethyl)amine with 2,5-dimethyl-3-thenoyl chloride. To a solution of bis(β-chloroethyl)amine, obtained from 37.5 g of the hydrochloride by treating an aqueous solution of the latter with a solution of 12 g of NaOH in 18 ml of water, followed by extraction with benzene (75 ml) and chloroform (25 ml) (the extract was dried over calcium chloride), was added a solution of 16.8 g of 2,5-dimethyl-3-thenoyl chloride in 20 ml of chloroform. The mixture was heated on the water bath for 25 hours. The precipitate of bis(β-chloroethyl)amine hydrochloride was filtered. The filtrate was treated with alcoholic HCl solution, and the mixture was evaporated in vacuo. The residue, a hard tarry substance, was washed with a little acetone. We obtained 19.9 g of crude product with m. p. 164-167°. After a double reprecipitation from dry acetone (or anhydrous alcohol) solution with ether the substance melted at 171-172°. The mixed melting point with the material obtained by method "a" was not depressed.

3-Bis(β-hydroxyethyl)aminomethyl-4-(β-hydroxyethyl)methylaminomethyl-2,5-dimethylthiophene (VII). To a solution of 5 g (0.037 mole) of 3-aminomethyl-4-methylaminomethyl-2,5-dimethylthiophene in 15 ml of methyl alcohol was added, with cooling, 4.5 g (0.1 mole) of ethylene oxide. The mixture was allowed to stand in the cold for several hours, and then it was kept at room temperature for 5 days. After distilling off the methyl alcohol in vacuo, the residue weighed 9 g. We took 3.5 g of the product and vacuum-distilled it; the substance boiled at 214° (2 mm).

Found %: C 56.69, 56.77; H 8.92, 9.09; S 10.35, 10.32. $C_{15}H_{28}O_3N_2S$. Calculated %: C 56.93; H 8.92; S 10.13.

3-Bis(β-chloroethyl)aminomethyl-4-(β-chloroethyl)methylaminomethyl-2,5-dimethylthiophene (II) dihydrochloride. With ice cooling, a solution of 10 g (0.084 mole) of thionyl chloride in 15 ml of chloroform was added dropwise to a solution of 8 g (0.025 mole) of 3-bis(β-hydroxyethyl)aminomethyl-4-(β-hydroxyethyl)-methylaminomethyl-2,5-dimethylthiophene in 35 ml of dry chloroform. The formation of a solid precipitate was observed here. On conclusion of adding the thionyl chloride, the mixture was heated for 30 minutes on the water bath. The chloroform and excess thionyl chloride were vacuum-distilled; the residue was washed carefully with acetone. We obtained 9 g of crude substance, which after recrystallization from alcohol and acetone melted at 183-185°; this salt was soluble in water, and difficultly soluble in alcohol.

Found %: C 41.06, 41.15; H 6.10, 6.26. $C_{15}H_{25}N_2Cl_3S \cdot 2HCl$. Calculated %: C 40.51; H 6.12.

3,4-Bis[di(β-chloroethyl)aminomethyl]-2,5-dimethylthiophene (III) dihydrochloride. To a cooled solution of 10.8 g (0.06 mole) of bis(β-chloroethyl)amine hydrochloride in 20 ml of water was added a solution of 3.48 g of NaOH in 7 ml of water. The obtained oil was extracted 3 times with benzene and once with chloroform. The combined extracts were dried over magnesium sulfate, and then mixed with a solution of 4 g (0.02 mole) of 3,4-bis(chloromethyl)-2,5-dimethylthiophene in 10 ml of chloroform; the mixture was heated on the water bath for 30 hours. The precipitate of bis(β-chloroethyl)amine hydrochloride was filtered. The solvents were removed from the filtrate by distillation. The residue was treated with alcoholic HCl solution, followed by evaporation of the mixture in vacuo. The residual solid, containing some oil as impurity, was treated with a little dry acetone and ether. We obtained 2 g of product; m. p. 169-170°. After precipitation from anhydrous alcohol (or acetone) solution with ether the substance melted at 176-178°.

Found %: C 38.77, 38.96; H 5.88, 5.77. $C_{16}H_{26}N_2Cl_4S \cdot 2HCl$. Calculated %: C 38.96; H 5.72.

2-Bis(β-hydroxyethyl)aminomethylthiophene (VIII) was prepared by the general Leuckart procedure [17] from 36.4 g (0.325 mole) of 2-thiophenecarboxaldehyde, 68.3 g (0.65 mole) of diethanolamine and 39 g (0.815 mole) of 96% formic acid by heating the mixture at 130-140° for 10 hours. We obtained 25.5 g (40%) or product.

B. p. 186-190° (7 mm), $n^{20}D$ 1.5497.

Literature data [17]: b. p. 156-158° (1 mm).

Found %: C 53.86, 54.05; H 7.50, 7.69; S 15.92, 15.92. $C_9H_{15}O_2NS$. Calculated %: C 53.70; H 7.51; S 15.93.

The picrate, after recrystallization from anhydrous alcohol, melted at 104-105°.

Found %: N 12.70. $C_{15}H_{18}O_9N_4S$. Calculated %: N 13.02.

2-Bis(β-chloroethyl)aminomethylthiophene (IV) hydrochloride. Obtained from 20.1 g (0.1 mole) of the aminoalcohol and 48 ml of thionyl chloride by the method described by Wilson [4].

A portion of the water solution of this hydrochloride was converted to the picrate, m. p. 96-98° (after recrystallization from alcohol).

Found %: C 38.99, 39.05; H 3.31, 3.30; N 12.15, 12.25. $C_{15}H_{16}O_7N_4Cl_2S$. Calculated %: C 38.55; H 3.45; N 11.98.

The picrate was converted to the hydrochloride (m. p. 102-103°) by triturating with dilute hydrochloric acid. The product crystallized when seeded with a crystal of the hydrochloride. We obtained 6.2 g (23.6%) of the hydrochloride.

Found %: C 38.86, 38.99; H 4.92, 5.04; Cl 13.01, 13.05 (Volhard). $C_9H_{14}NCl_3S$. Calculated %: C 39.35; H 5.14; Cl 12.91.

SUMMARY

In order to obtain antitumor compounds, we synthesized and characterized the hydrochloride of 3-bis(β-chloroethyl)aminomethyl-2,5-dimethylthiophene, the dihydrochlorides of 3-bis(β-chloroethyl)aminomethyl-4-(β-chloroethyl)methylaminomethyl-2,5-dimethylthiophene and 3,4-bis[di(β-chloroethyl)aminomethyl]-2,5-dimethylthiophene, and the corresponding aminoalcohols.

LITERATURE CITED

[1] V. Prelog and V. Stepan, Collection Czech. Chem. Commun. 7, 93 (1935).

[2] W. C. J. Ross, J. Chem. Soc. (1949), 183; W. C. J. Ross and G. P. Warwick, J. Chem. Soc. (1956), 1724.

[3] L. F. Larionov and G. N. Platonova, Voprosy Onkologii 5, 36 (1955).

[4] E. Wilson and M. Tishler, J. Am. Chem. Soc. 73, 3635 (1951); B. M. Mikhailov and T. K. Kozminskaya, Zhur. Obshchei Khim. 26, 2042 (1956).*

[5] V. P. Bronovitskaya, Dissertation [In Russian] (Moscow, 1957).

[6] O. F. Ginzburg, B. A. Porai-Koshits, M. I. Krylova, and S. M. Lotareichik, Zhur. Obshchei Khim. 27, 411 (1957);* G. N. Platonova, Byull. Eksptl. Biol. Med. 8, 93 (1957); E. Hirschberg, A. Gellhorn, and W. S. Gump, Cancer Research 17, 904 (1957).

[7] R. Jones, Jr., C. C. Price, and A. K. Sen, J. Org. Chem. 22, 783 (1957).

[8] C. C. Stock, S. Buckley, K. Sugiura, and C. P. Rhoads, Cancer Res. 11, 432 (1951).

* Original Russian pagination. See C. B. translation.

[9] M. S. Kondakova and Ya. L. Gol'dfarb, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk (1958), 590.*

[10] A. I. Kravchenko, Voprosy Onkologii 6, 84 (1955).

[11] E. Campaigne and H. L. Thomas, J. Am. Chem. Soc. 77, 5365 (1955); E. Campaigne and W. C. McCarthy, J. Am. Chem. Soc. 76, 4466 (1954); K. Dittmer, J. Am. Chem. Soc. 71, 1205 (1949); R. G. Garst, E. Campaigne, and H. G. Day, J. Biol. Chem. 180, 1013 (1949).

[12] R. W. Wissler, L. F. Frazier, K. H. Soules, P. Barker, and E. C. Bristow, Arch. Pathol. 62, 62 (1956).

[13] M. Rabinovitz, M. E. Olson and D. M. Greenberg, J. Biol. Chem. 210, 837 (1954).

[14] R. M. Acheson, K. E. MacPhee, P. G. Philpott, and J. A. Barltrop, J. Chem. Soc. (1956), 698.

[15] O. M. Friedman and A. M. Seligman, J. Am. Chem. Soc. 70, 3082 (1948).

[16] Ya. L. Gol'dfarb and M. S. Kondakova, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk (1956), 495.*

[17] P. A. S. Smith and A. J. MacDonald, J. Am. Chem. Soc. 72, 1037 (1950).

* Original Russian pagination. See C. B. translation.

ISOMERIC TRANSFORMATIONS OF THE THIOPHENE RING

IV. ISOMERIZATION OF 2-THIENYLMETHANOL

V. S. Egorova

Kuibyshev Industrial Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 107-109, January, 1960

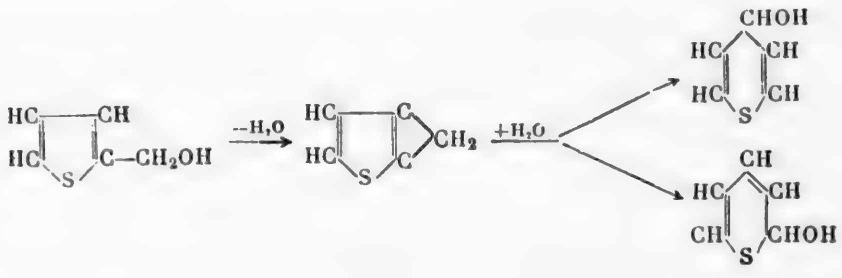
Original article submitted November 15, 1958

It was shown by Dem'yanov [1] that cyclic primary amines are easily isomerized when treated with nitrous acid ("Dem'yanov reaction"); Dem'yanov gave the general theory and proposed a mechanism for this reaction [1]. The tenets of the theory received further development in the investigations of N. I. Putokhin [2], who operated with nitrogen heterocycles, and in the studies of N. V. Williams [3], who worked with oxygen heterocycles. Sulfur heterocycles of the thiophene series remained unstudied.

In our previous papers [4-6], it was shown that isomeric expansion is also inherent to the thiophene ring and that it goes quite smoothly under the conditions of the Dem'yanov reaction. We were able to show that 2-thienylmethylamine is converted to hydroxythiapyran when treated with nitrous acid.

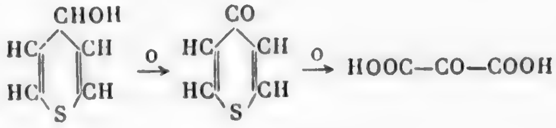
However, the Dem'yanov isomerization of carbocyclic molecules was studied not only relative to the action of nitrous acid on cyclic amines, but also relative to the reaction of cyclic alcohols with oxalic and hydrogen halide acids [9]. To obtain more complete information on this subject, we undertook a study of the isomerization of alcohols of the thiophene series. We investigated the reaction of 2-thienylmethanol with oxalic acid. 2-Thienylmethanol, synthesized by the Grignard – Ziegler method [10-12] from thienylmagnesium iodide and formaldehyde, was reacted with oxalic acid under various conditions.

According to Dem'yanov's data [1-9], the reaction of 2-thienylmethanol with oxalic acid should result in its dehydration and isomerization to a compound with a six-membered ring, namely hydroxythiapyran.



The reaction was run at different temperatures (from 20 to 90°); both anhydrous and hydrated oxalic acid were used. Pronounced tarring was observed. However, after a number of experiments we were able to isolate a small amount of a substance whose properties proved to be similar to those of the hydroxythiapyran that we had obtained earlier by the isomerization of thienylmethylamine [4, 6].

The hydroxythiapyran was characterized via its oxidation products. Here we obtained thiapyrone and mesoxalic acid.



EXPERIMENTAL

A mixture of 5.7 g (0.05 mole) of 2-thienylmethanol and 12.6 g (0.1 mole) of oxalic acid in a round-bottomed flask, fitted with a reflux condenser and calcium chloride tube, was kept at 20° for 6 days, and then it was heated on the water bath for 20 hours at 55°. The dark mass obtained was treated with 100 ml of water. This led to the separation of a substantial amount of a viscous, oily, brown liquid, insoluble in water. The mixture was extracted with ether, and the ether solution was shaken with calcium chloride solution to remove oxalic acid. Removal of the ether left about 2 g of a substance, whose structure was established by oxidation.

One gram of the substance was treated with 0.1% potassium permanganate solution in the presence of alkali (0.16 g per 100 ml). The oxidation went rapidly at the start, then more slowly, and finally ceased completely after the consumption of 800 ml of the potassium permanganate solution. A portion of the oily substance remained undissolved. The precipitate of manganese dioxide and tar was filtered. The water solution was evaporated carefully on the water bath at 60° and the residue was extracted with ether. Removal of the ether left a small amount of colorless needles in the flask. The needles had m. p. 110°.

Found %: C 53.40, 53.52; H 3.41, 3.45; S 28.41, 28.50. C_5H_4OS. Calculated %: C 53.57; H 3.57; S 28.57.

With aqueous mercuric chloride solution the substance gives a compound with m. p. 189°, while reaction with semicarbazide gives colorless needles with m. p. 227°.

The data obtained by us coincide with the literature data for thiapyrone [7].

Thiapyrone, m. p. 110°; compound with mercuric chloride, m. p. 189°.

The water solution from the ether extraction was acidified and extracted again with ether. Removal of the ether left some colorless crystals with m. p. 121° (decomp.).

Found %: C 26.10, 26.51; H 2.52, 2.43. $C_3H_2O_4 \cdot H_2O$. Calculated %: C 26.47; H 2.94.

Semicarbazone, m. p. 216°; oxime, m. p. 136° (decomp.).

These results correspond to the literature data for mesoxalic acid [8]: m. p. 121° (decomp.); oxime, m. p. 136° (decomp.).

SUMMARY

The reaction of 2-thienylmethanol with oxalic acid was investigated.

It was established that the dehydration of 2-thienylmethanol with oxalic acid leads to isomerization of the five-membered ring to a six-membered ring, and in this way, it was shown that the reaction discovered by Dem'yanov for the expansion of cyclic systems also applies to alcohols of the thiophene series.

LITERATURE CITED

[1] N. Ya. Dem'yanov, Collection of Papers [In Russian] (Moscow, Acad. Sci. USSR Press, 1936), p. 238.

[2] N. Ya. Dem'yanov, Uspekhi Khim. 3, 493 (1934); N. I. Putokhin, Zhur. Russ. Fiz.-Khim. Obshchestva 59, 761 (1927); 62, 2216, 2226 (1930); Zhur. Obshchei Khim. 2, 290 (1932).

[3] N. V. Williams, Doklady Akad. Nauk SSSR 16, 424 (1930).

[4] N. I. Putokhin and V. S. Egorova, Zhur. Obshchei Khim. 10, 1873 (1940).

[5] N. I. Putokhin and V. S. Egorova, Zhur. Obshchei Khim. 18, 1866 (1948).

[6] N. I. Putokhin and V. S. Egorova, Doklady Akad. Nauk SSSR 96, 293 (1954).

[7] F. Arndt and N. Bekir, Ber. 63, 2395 (1930).

[8] W. Dennis, J. Am. Chem. Soc. 38, 586 (1907); E. Fischer, Lieb. Ann. 215, 283 (1882).

[9] N. Ya. Dem'yanov, Collection of Papers [In Russian] (Moscow, Acad. Sci. USSR Press, 1936), p. 310.

[10] K. Ziegler, Ber. 34, 737 (1901).

[11] W. Steinkopf, Lieb. Ann. 540, 14 (1939).

[12] Organic Syntheses (Editors: Roger Adams, et al.), Vol. III, p. 49 (1935).

ALKYLATION OF FLUOROBENZENE WITH PROPYLENE AND CYCLOHEXENE IN THE PRESENCE OF $BF_3 \cdot H_3PO_4$

V. G. Vakhtin and S. V. Zavgorodnii

Voronezh State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 109-111, January, 1960

Original article submitted January 15, 1959

As a continuation of our studies on the alkylation of halobenzenes with olefins [1], we discuss in the present paper the alkylation of fluorobenzene with propylene and cyclohexene in the presence of the $BF_3 \cdot H_3PO_4$ complex. As our studies revealed, fluorobenzene is easily alkylated with propylene in the presence of $BF_3 \cdot H_3PO_4$ catalyst to yield a mixture of mono- and diisopropylbenzenes. The isopropylfluorobenzene is mainly the p-isomer; the dialkylate is 1,3-diisopropyl-4-fluorobenzene. The maximum yields of the mono- and diisopropylfluorobenzenes are respectively 85 and 15%, and they are obtained at a molar ratio of fluorobenzene propylene and catalyst equal to 3 : 1 : 0.3, a temperature of 80°, and a propylene feed rate of 0.17 mole per mole of fluorobenzene per hour.

The amount of catalyst in the range 0.15-0.3 mole per mole of propylene, at 60°, is without noticeable effect on the yield and composition of the alkylate. In the presence of 0.5 mole of catalyst and the same reactant ratio the yield of isopropylfluorobenzene decreases, which is apparently due to a partial polymerization of the olefin under these conditions. The temperature exerts an important influence on the reaction. At a constant reactant and catalyst ratio of 3 : 1 : 0.3 and temperatures of 30, 60, and 80° the yields of isopropylfluorobenzene are respectively 68, 78, and 85%.

The alkylation of fluorobenzene with cyclohexene yields only p-cyclohexylfluorobenzene. The optimum reaction conditions, where the yield of the cyclohexylfluorobenzene is 62%, are a molar ratio of reactants and catalyst equal to 3 : 1 : 0.3, a temperature of 30° and a cyclohexene feed rate of 0.056 mole per mole of fluorobenzene per hour. Also in this reaction the temperature and the molar ratios of the reactants exert an important influence on the yield of alkylate. Thus, at a molar ratio of fluorobenzene, cyclohexene and catalyst equal to 3 : 1 : 0.3 and temperatures of 17, 30, and 60° the yields of p-cyclohexylfluorobenzene are respectively 12, 62, and 56%. Increasing the molar ratio fluorobenzene : cyclohexene to 5 : 1 or decreasing it to 2 : 1 causes the yield of p-cyclohexylfluorobenzene to decrease from 62 to 39 and 56%, respectively.

To prove the structure of the alkylation products we oxidized them with nitric acid to the corresponding acids, and we also subjected them to autoxidation to the hydroperoxides with subsequent cleavage to the phenols and ketones. Here it was found that both p-isopropylfluorobenzene and p-cyclohexylfluorobenzene show relatively slow oxidation to the hydroperoxides in the presence of manganese resinate, cobalt acetate and sodium hydroxide. In the case of p-isopropylfluorobenzene the maximum hydroperoxide concentration is reached after 27 hours and is 23.2%, while in the case of p-cyclohexylfluorobenzene the maximum concentration is reached after 10 hours and is 12%. The hydroperoxides begin to decompose on further oxidation. p-Isopropylfluorobenzene hydroperoxide decomposes with the formation of p-fluoroacetophenone, while p-cyclohexylfluorobenzene hydroperoxide is converted to the final products, namely p-fluorobenzoic acid and glutaric acid.

EXPERIMENTAL

The fluorobenzene needed for reaction was prepared from benzenediazonium fluoborate [2], and it had b. p. 84-85°, d^{20}_4 1.0176, $n^{20}D$ 1.4624.

Cyclohexene and propylene were obtained by the dehydration of the corresponding alcohols. Cyclohexene had b. p. 82°, d^{20}_4 0.8127, $n^{20}D$ 1.4476.

Alkylation of fluorobenzene with propylene. Into a three-necked flask, fitted with a stirrer, thermometer and bubbler, were charged the weighed amounts of catalyst and fluorobenzene and then with vigorous stirring, at the desired temperature, a stream of propylene was added from a gas holder at a rate of 3.5 liters per hour. After adding a definite amount of propylene, the mixture was stirred at the same temperature for another 2 hours, washed with water, then with 15% sodium carbonate solution, again with water, and after drying over aluminum oxide, the reaction products were distilled from a flask fitted with a Vigreux column.

The p-isopropylfluorobenzene, after additional washing with concentrated sulfuric acid and redistillation, had the following constants:

B. p. 153-155°, d^{20}_4 0.9646, $n^{20}D$ 1.4733, MR_D 42.3; Calc. 41.1.

Found: M 137.3. $C_9H_{11}F$. Calculated: M 138.0.

When oxidized with 30% nitric acid the compound was converted to p-fluorobenzoic acid in 70% yield. M. p. 181-182°. Literature data [3]: m. p. 182°.

Autoxidation of p-isopropylfluorobenzene. In a column fitted with a sealed Schott filter was placed a mixture of 30.7 g of p-isopropylfluorobenzene and 100 mg of NaOH, and after heating to 110°, a stream of air was passed through the mixture for 2 hours at an average velocity of 150 ml/min. Then 0.8 mg of manganese resinate and 20 mg of cobalt acetate were added, and the passage of air was continued at the same temperature. After 27 hours, the concentration of the hydroperoxide in the solution reached 23.2%, and after 33 hours, it had dropped to 19.5% (determined iodometrically). Placing 26.8 g of the hydroperoxide solution of the indicated concentration in a three-necked flask, fitted with a mechanical stirrer, thermometer and reflux condenser, we decomposed the hydroperoxide completely by the dropwise addition of concentrated hydrochloric acid solution at a temperature not exceeding 60°. A total of 10 ml of acid was added in 3 hours. The mixture was neutralized with 10% NaOH solution. The acetone (characterized through the 2,4-dinitrophenylhydrazone with m. p. 123-124°) was removed from the alkaline layer by distillation; acidification of the residue gave 1.6 g of p-fluorophenol, or 61.5%, based on the hydroperoxide taken for decomposition. The p-fluorophenoxyacetic acid had m. p. 102-102.5°. Literature data [4]: m. p. 102-103°.

From the organic layer, after distilling off the unreacted p-isopropylfluorobenzene, we isolated 2.6 g of p-fluoroacetophenone, apparently formed in the autoxidation process through decomposition of the hydroperoxide: b. p. 193°, d^{20}_4 1.0731, $n^{20}D$ 1.5020. Its oxidation with 20% nitric acid gave p-fluorobenzoic acid in 83% yield. The 2,4-dinitrophenylhydrazone had m. p. 229-231°.

1,3-Diisopropyl-4-fluorobenzene was obtained as a colorless, mobile liquid.

B. p. 76-78° (8 mm), d^{20}_4 0.9352, $n^{20}D$ 1.4783, MR_D 55.6; Calc. 53.9.

Found: M 179.1. $C_{12}H_{17}F$. Calculated: M 180.0.

Its oxidation with 30% nitric acid gave 4-fluoroisophthalic acid with m. p. 298-301°. Literature data [5]: m. p. 300-301°.

Alkylation of fluorobenzene with cyclohexene. The reaction was studied in the same apparatus used for the alkylation of fluorobenzene with propylene, except that the bubbler was replaced by a dropping funnel. The cyclohexene was added in drops to the mixture of fluorobenzene and catalyst at the desired temperature and with constant stirring. When the calculated amount of cyclohexene had been added, the mixture was worked up as described earlier. In the experiments run at 60° the alkylation products were washed well with concentrated sulfuric acid to remove the cyclohexene dimer. Such washing was not required in the experiments run at 30°, since quite pure p-cyclohexylfluorobenzene was obtained here.

p-Cyclohexylfluorobenzene, obtained as the sole cycloalkylation product, is a colorless liquid with a pleasant odor.

B. p. 231-233°, d^{20}_4 0.0182, $n^{20}D$ 1.5074, MR_D 52.8; Calc. 53.7.

Found: M 180.8. $C_{12}H_{15}F$. Calculated: M 178.0.

Oxidation of the compound with 30% nitric acid gave p-fluorobenzoic acid in 52% yield: m. p. 181-182.5°. Literature data [3]: m. p. 182°.

Autoxidation of p-cyclohexylfluorobenzene. A mixture of 50.5 g of p-cyclohexylfluorobenzene and 43 mg of NaOH was placed in a flask. The mixture was heated to 110°, and then a stream of air was passed through it for 2 hours at a rate of 200 ml/min. This was followed by the addition of 11.2 mg of cobalt acetate and 3 g of manganese resinate, and the passage of air was continued. After 10 hours, the hydroperoxide content in the solution reached 12%. The further passage of air caused the hydroperoxide concentration to decrease and after 30 hours it was equal to zero. The reaction products were neutralized with alkali. We isolated 39.5 g of unoxidized p-cyclohexylfluorobenzene from the organic layer. Acidification of the alkaline layer gave 2.3 g (57%) of p-fluorobenzoic acid and 0.35 g (10%) of glutaric acid with m. p. 95-96°. Literature data [3]: m. p. 97°.

SUMMARY

A study was made of the alkylation of fluorobenzene with propylene and cyclohexene under various conditions, using the complex of boron fluoride with orthophosphoric acid as catalyst. 1-Isopropyl-4-fluorobenzene, 1-cyclohexyl-4-fluorobenzene and 1,3-diisopropyl-4-fluorobenzene were isolated and characterized.

LITERATURE CITED

[1] S. V. Zavgorodnii and V. G. Vakhtin, Sbornik Trudy Voronezh. Otdel. Vsesoyuz. Khim. Obshchestvo im. D. I. Mendeleeva 1, 195 (1957).

[2] Organic Syntheses, Coll. Vol. II, p. 295 (1943).

[3] Heilbron, Dictionary of Organic Compounds, Vol. II, 71 (1936).

[4] C. M. Suter, E. J. Lawson, and P. G. Smith, J. Am. Chem. Soc. 61, 161 (1939).

[5] V. V. Korshak, G. S. Kolesnikov, and A. S. Fedorova, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk (1958), 353.*

* Original Russian pagination. See C. B. translation.

ABSORPTION SPECTRA OF MONOAZO DYES OF THE ACID RED TYPE

N. A. Boguslavskaya, B. M. Bogoslovskii, and B. M. Yavorskii

All-Union Correspondence Institute of the Textile and Light Industry

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 112-115, January, 1960

Original article submitted October 24, 1958

The relation between absorption spectra and the molecular structure of azo dyes has been discussed by many authors [1-4]. From [4], it is known that introducing a sulfo group into the dye molecule, due to the presence of the 2^+ sulfur atom, causes the electron pairs to shift toward the carbon attached to the sulfur. For this reason, the effect exerted by this group is analogous to the effect of other electrophilic substituents. The introduction of electron-donor substituents, which include the auxochrome groups OH and NH_2, into the naphthalene nucleus causes a bathochromic shift of the absorption bands belonging to the original products of the dye (azo-component). The stronger effect of the amino group is explained by the somewhat greater lability of the unshared electrons of the nitrogen atom when compared with the electrons of the oxygen, due to the smaller nuclear charge of the nitrogen atom. The simultaneous presence of the SO_3H group and the auxochrome groups OH and NH_2 in a chain of conjugated bonds leads to an even sharper shift of the absorption maximum toward longer wavelengths.

The present paper is part of a general investigation on the relationship between absorption spectra and the molecular structure of monoazo dyes. Its objective was to ascertain the following.

1) The influence exerted by the position of the sulfo group in the dye molecule on the absorption spectrum.

2) The effect of replacing the hydroxyl group by the amino group, with the position of the sulfo group kept constant, on the absorption spectrum.

3) The change in the absorption maxima when the hydroxyl and amino groups are shifted from the α- to the β-position in the naphthalene ring.

The investigated dyes were obtained by the coupling of the isomeric naphthylaminesulfonic acids with the corresponding α - and β-naphthols or naphthylamines. We studied a total of 24 monoazo dyes. The compounds used as the azo-components in the synthesis of these dyes were the six isomeric sulfonic acids of α-naphthylamine: 1,2-, 1,4-, 1,5-, 1,6-, 1,7-, and 1,8-naphthylaminesulfonic acid.

The dyes were synthesized according to the scheme:

$$HSO_3C_{10}H_6{-}NH_2 \rightarrow HSO_3C_{10}H_6N_2Cl + C_{10}H_7\ \mathrm{Aux} \rightarrow HSO_3{-}C_{10}H_6{-}N_2{-}C_{10}H_6\ \mathrm{Aux}$$
$$\mathrm{Aux} = NH_2 \text{ or } OH$$

The azo dyes were purified by conversion to the water-insoluble benzidine salt of the dye and its subsequent repeated recrystallization from water [5]. The purity of the obtained sodium salts of the dyes was determined by titration with titanium trichloride solution, and was verified by the constancy of the absorption bands and the molar coefficient of extinction ϵ in the long-wave portion of the spectrum. The purity of the dyes was 97-99%.

The absorption spectra of the dye solutions were taken in the 220-700 mμ region using a Beckman quartz spectrophotometer. Distilled water functioned both as solvent and as the blank. Preliminary experiments established that the solvent absorbs very little light. Since the solutions of some of the dyes exhibited a high optical density, we used a lower solution concentration when taking their spectra.

By means of special experiments, it was established that dyes prepared at different times were identical, and it was also established that both the synthesis and the purification of the dyes were reproducible.

Absorption Maxima of Monoazo Dyes (in mμ)

Diazo component	Azo component			
	α-naphthol	β-naphthol	α-naphthylamine	β-naphthylamine
1,2-Naphthylaminesulfonic acid	278, 485	278, 310, 494	270, 480	275, 346, 465
1,4-Naphthylaminesulfonic acid	266, 452	280, —, 506	272, 500	276, 340, 475
1,5-Naphthylaminesulfonic acid	268, —	—, 380, 505	275, 465	280, 350, 480
1,6-Naphthylaminesulfonic acid	280, 500	285, —, 505	280, 470	255, 355, 475
1,7-Naphthylaminesulfonic acid	267, 510	283, —, 535	274, 468	265, 345, 480
1,8-Naphthylaminesulfonic acid	274, 502	—, 400, 480	285, 475	278, 334, 490

In addition, it was established that Beer's law holds for water solutions of the dyes up to a concentration of 20 mg/liter.

The absorption maxima of all of the dyes investigated by us are given in the table. The absorption spectra of some of the dyes prepared from α- and β-naphthol are shown in Figs. 1 and 2, while the absorption spectra of some of the dyes obtained from α- and β-naphthylamine are shown in Figs. 3 and 4.

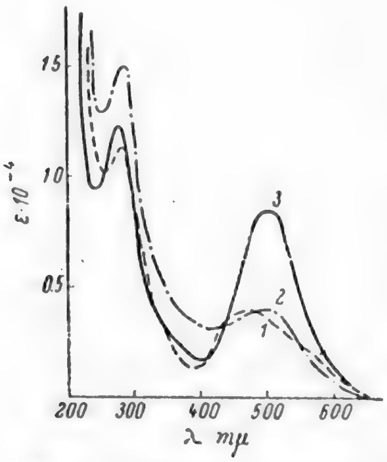


Fig. 1. Absorption spectra of dyes derived from α-naphthol. 1) 1,2-Naphthylaminesulfonic acid — α-naphthol; 2) 1,6-naphthylaminesulfonic acid — α-naphthol; 3) 1,8-naphthylaminesulfonic acid — α-naphthol.

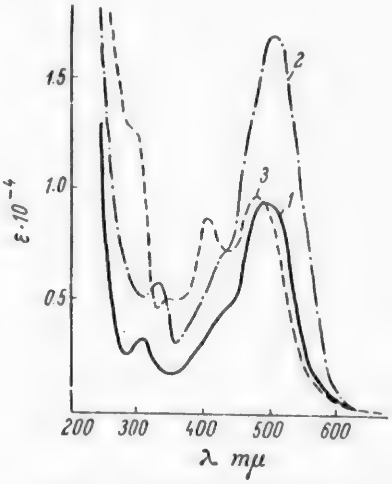


Fig. 2. Absorption spectra of dyes derived from β-naphthol. 1) 1,2-Naphthylaminesulfonic acid — β-naphthol; 2) 1,5-naphthylaminesulfonic acid — β-naphthol; 3) 1,8-naphthylaminesulfonic acid — β-naphthol.

The obtained absorption maxima indicate that a general rule is observed in the given case regarding the distribution of the absorption maxima. The absorption bands belonging to the starting intermediates: naphthylaminesulfonic acid, naphthalene, and naphthol [6, 7], are repeated in the short-wave portion of the spectrum. A very intense absorption band, λ_{max} = 460-500 mμ, belonging to the dye, appears in the long-wave portion of the spectrum. The weak naphthalene band, λ_{max} = 320 mμ, corresponding to electron transition and polarized along the short b — b' axis [8], disappears in some of the isomeric dyes. In the case of the amino dyes this band is shifted somewhat toward the long-wave side (λ_{max} = 335-350 mμ).

Changing the position of the sulfo group in the α-monoazo dye molecules fails to be accompanied by a regular shift of the absorption maxima, either in the short-wave or the long-wave portion of the spectrum. For the β-derivatives with the sulfo group in either the 2 or the 8 position with respect to the azo group a somewhat smaller shift (by 25-50 mμ) of the absorption band is observed in the long-wave portion of the spectrum when compared with the other isomers.

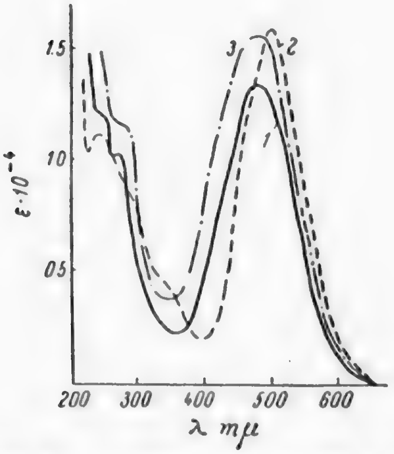


Fig. 3. Absorption spectra of dyes derived from α-naphthylamine. 1) 1,2-Naphthylaminesulfonic acid — α-naphthylamine; 2) 1,4-naphthylaminesulfonic acid — α-naphthylamine; 3) 1,7-naphthylaminesulfonic acid — α-naphthylamine.

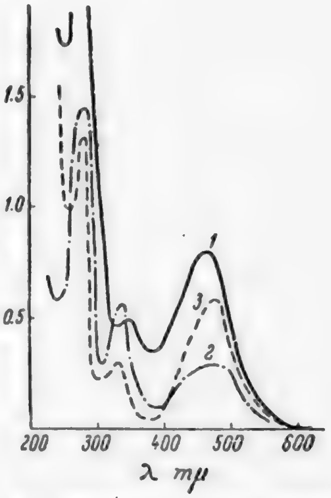


Fig. 4. Absorption spectra of dyes derived from β-naphthylamine. 1) 1,2-Naphthylaminesulfonic acid — β-naphthylamine; 2) 1,4-naphthylaminesulfonic acid — β-naphthylamine; 3) 1,8-naphthylaminesulfonic acid — β-naphthylamine.

The introduction of either the OH or the NH_2 group into the naphthalene ring has little effect on the position of those absorption maxima of naphthalene located in the ultraviolet portion of the spectrum (λ_{max} = = 220 and 275 mμ). The effect of the amino and hydroxyl groups is somewhat different in the long-wave portion. For most of the isomers (nine out of eleven) the hydroxyl group exerts a greater influence on the position of the absorption maxima than does the amino group. The absorption maxima for the hydroxy isomers are some 20-25 mμ above those for the amino isomers.

It is obvious that this may be linked with the ionization of the hydroxyl group, which in the given case is accompanied by the appearance of a constant effective negative charge on the oxygen atom, which leads to enhancing the electron-donor properties of the hydroxyl group. Ionization of the amino group, as is known, occurs only in acid medium.

Changing the position of the OH group in the dye molecule from α to β is accompanied by a slight shift in λ_{max} toward longer wavelengths, which is possibly linked with the creation of intramolecular hydrogen bonding between the hydrogen of the hydroxyl and the nitrogen of the azo group [9, 10]. It should be mentioned that in addition to this a shift of the hydroxyl group from the o-position to the azo group is accompanied by the

appearance of a new and very weak absorption band around 400 mμ, which is especially manifest for the dyes that have a sulfo group in the peri-position with respect to the azo group.

A shift of the amino group from the α- to the β-position is accompanied by the appearance of a fairly strong absorption maximum around 345 mμ, which is absent in all of the other cases, and also of a slight bathochromic effect in the long-wave portion of the spectrum (see table).

The authors wish to thank L. I. Belen'kii and M. E. Kazanskaya for their assistance in carrying out the present investigation.

SUMMARY

1. Twenty-four monoazo dyes of the Acid Red type were synthesized and their absorption spectra were taken in the 220-700 mμ region.

2. The effect of position of the sulfo group and introduction of hydroxyl and amino groups on the absorption spectra of various isomeric dyes was discussed.

LITERATURE CITED

[1] W. Borsche, W. Müller, and C. A. Bodenstein, Ann. 472, 201 (1929).

[2] A. Burawoy and I. Markowitsch, Ann. 503, 180 (1933).

[3] R. Kuhn and F. Bär, Ann. 516, 143 (1935).

[4] V. V. Perekalin, Zhur. Obshchei Khim. 17, 1788 (1947).

[5] B. M. Bogoslovskii, Zhur. Priklad. Khim. 28, 659 (1956).*

[6] H. G. de Laszlo, Proc. Royal Soc. (London), 111A, 355 (1926).

[7] H. H. Hodgson and D. E. Hathway, Trans. Faraday Soc. 41, 115 (1945).

[8] L. V. Smirnov, Trudy Leningrad. Tekhnol. Inst. Pishchevoi Prom. 12, 258 (1955).

[9] V. V. Perekalin and M. V. Sevast'yanova, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk 12, 586 (1948); Zhur. Obshchei Khim. 21, 1329 (1951).*

[10] D. N. Shigorin and N. S. Dokunikhin, Zhur. Fiz. Khim. 29, 1958 (1955).

* Original Russian pagination. See C. B. translation.

TERTIARY TRIATOMIC ALCOHOLS OF ACETYLENE SERIES AND THEIR TRANSFORMATIONS

XIV. HYDRATION OF 3,4,7-TRIMETHYL-5-OCTYNE-3,4,7-TRIOL AND 2,3,6-TRIMETHYL-4-OCTYNE-2,3,6-TRIOL

V. I. Nikitin and A. B. Zegel'man

Institute of Chemistry, Academy of Sciences of the Tadzhik SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 115-124, January, 1960

Original article submitted January 12, 1959

In this paper we present some data relating to the hydration of two isomeric tertiary glycerols of the acetylene series, namely 3,4,7-trimethyl-5-octyne-3,4,7-triol (I) and 2,3,6-trimethyl-4-octyne-2,3,6-triol (IX).

Investigations on the hydration of two other acetylenic triols, namely 3,4,7-trimethyl-5-nonyne-3,4,7-triol and 2,3,6-trimethyl-4-heptyne-2,3,6-triol, were published earlier [1, 2].

The data obtained in the hydration of all four triols indicate that tertiary glycerols of the acetylene series undergo extremely interesting and complex transformations under the conditions of the Kucherov reaction, resulting in the formation of a bicyclic system composed of two substituted heterocycles, a tetrahydropyran and a tetrahydro-γ-pyrone, connected by a semicyclic bond.

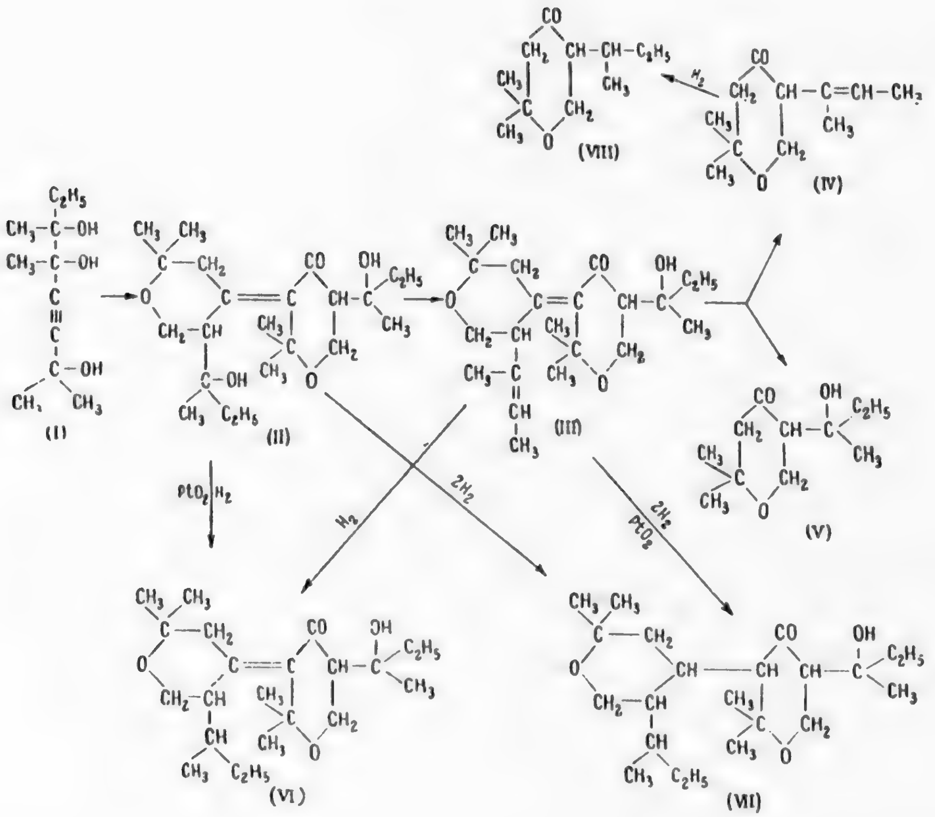
In our work we found that the hydration of 3,4,7-trimethyl-5-octyne-3,4,7-triol (I) at a temperature not exceeding 70° leads to the formation of 2,2-dimethyl-5-sec-hydroxybutyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (II) (see Scheme 1). If the reaction is run on the boiling water bath or if (II) is heated with sulfuric acid at the same temperature, then three products are obtained: 2,2-dimethyl-5-sec-butenyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (III), as the result of incomplete dehydration of (II), while 2,2-dimethyl-5-sec-butenyltetrahydro-γ-pyrone (IV) and 2,2-dimethyl-5-sec-hydroxybutyltetrahydro-γ-pyrone (V) are obtained as the result of the hydrolytic cleavage of (III). Attempts to react (V) with H_2SO_4 and $H_2SO_4 + HgSO_4$ proved unsuccessful. Neither is the compound oxidized by permanganate.

Our attempts to oxidize (II) and (V) to the corresponding aldehydes using Beckmann reagent gave negative results, the same as in the previous case [1, 3], which testifies to the tertiary character of the hydroxyl groups in these compounds.

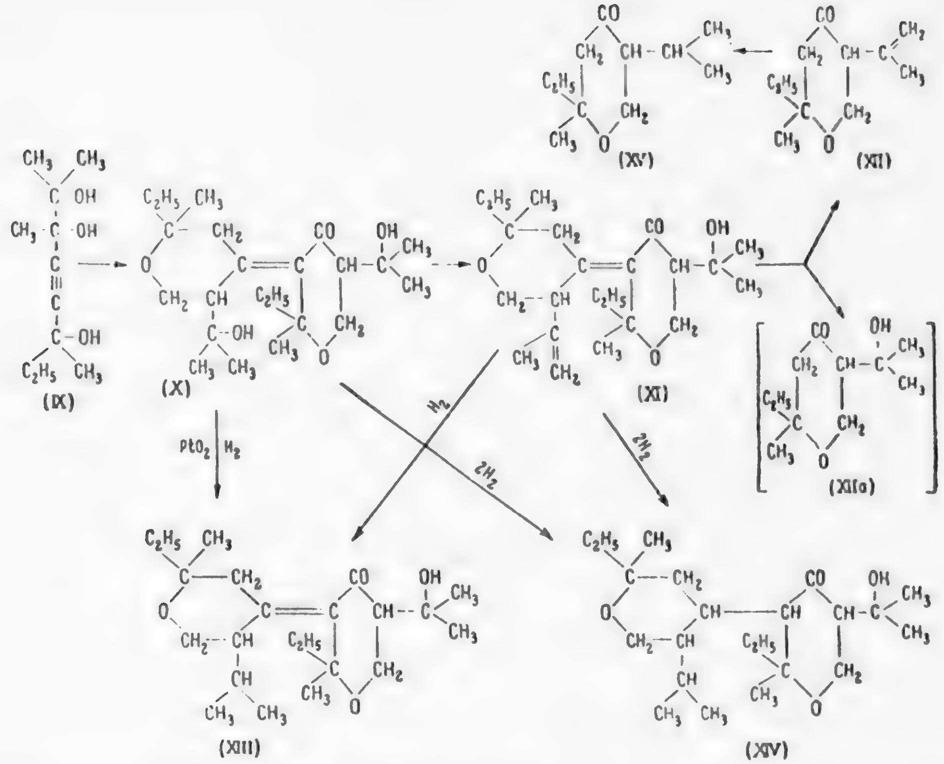
The structure of (III) is proved by oxidation of the compound with potassium permanganate, but this also proves the structure of (II), since (III) is obtained by the dehydration of (II). We were unable to oxidize (IV) due to its small yield.

The hydrogenation of either (II) or (III) with one mole of hydrogen causes both compounds to reduce to the same 2,2-dimethyl-5-sec-butyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (VI). This serves as evidence that in the hydrogenation of (III) the first mole of hydrogen reduces the butenyl radical in the compound to the sec-butyl, while in the hydrogenation of (II) the first mole of hydrogen reduces the hydroxyl group of the tetrahydropyran ring, in both cases leaving the semicyclic bond completely untouched.

The hydrogenation of either (II) or (III) with two moles of hydrogen yields 2,2-dimethyl-5-sec-butyltetrahydropyranyl-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (VII). The hydrogenation of (IV) yields 2,2-dimethyl-5-sec-butyltetrahydro-γ-pyrone (VIII) (see Scheme 1).



The hydration of 2,3,6-trimethyl-4-octyne-2,3,6-triol (IX), being an isomer of (I), caused the same transformations which occurred in the hydration of acetylenic glycerol (I) (see Scheme 2). In this case, 2-methyl-2-ethyl-5-hydroxyisopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (X) and 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XI) were obtained even at 80°. If the reaction is completed by heating on the boiling water bath, then besides (XI), the reaction products contain the hydrolytic cleavage product of (XI), namely 2-methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone (XII). Neither (X) nor 2-methyl-2-ethyl-5-hydroxypropyltetrahydro-γ-pyrone (XIIa) is present in the reaction mixture in this case: the first (X) is dehydrated to (XI), and the second (XIIa) is dehydrated to (XII).



The special dehydration of (X) with sulfuric acid solution (1 : 6) gave (XI), while treatment of the latter with the same sulfuric acid solution gave 2-methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone (XII), which serves as evidence that it is not (X) that undergoes hydrolytic cleavage, but instead it is its incomplete dehydration product (XI). The structure of (XI) and (XII) is proved by their oxidation with potassium permanganate, which also proves the structure of (X).

The hydrogenation of the substituted tetrahydropyranylidenetetrahydropyrone (X) with one mole of hydrogen gave 2-methyl-2-ethyl-5-isopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XIII), which is also obtained if (XI) is hydrogenated with one mole of hydrogen, thus confirming the structure of (XIII).

The hydrogenation of (X) with two moles of hydrogen gave 2-methyl-2-ethyl-5-isopropyltetrahydropyranyl-2'-methyl-2'-ethyl-5'-hydroxypropyltetrahydro-γ-pyrone (XIV).

2-Methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone (XII) hydrogenates to 2-methyl-2-ethyl-5-isopropyl-tetrahydro-γ-pyrone (XV).

EXPERIMENTAL

3,4,7-Trimethyl-5-octyne-3,4,7-triol (I)

Hydration of (I). (I) was prepared by the condensation of methylethylacetylcarbinol with dimethylethynyl-carbinol and had the following constants: b. p. 118-119° (2 mm), and $n^{20}D$ 1.4794, which corresponds to [4].

a) To 10 g of 3,4,7-trimethyl-5-octyne-3,4,7-triol in a three-necked flask, fitted with a reflux condenser, mechanical stirrer and thermometer, was added a cold mixture of 18 ml of water, 3 ml of concentrated H_2SO_4 and 0.5 g of $HgSO_4$. The temperature of the reaction mixture was raised to 70°. The reaction product after cooling was extracted with ether. The ether extracts were washed with sodium carbonate solution and water, and then dried over Na_2SO_4. Removal of the ether by distillation left 5.8 g (60.8%) of white silky crystals with m. p. 125-126°

(from petroleum ether), being 2,2-dimethyl-5-sec-hydroxybutyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (II).

Found %: C 68.95, 68.95; H 10.11, 9.99; OH 8.90, 8.70. M 399.8. $C_{22}H_{38}O_5$. Calculated %: C 69.10; H 9.95; OH 8.90. M 382.0.

b) A mixture of 36 ml of H_2O, 6 ml of concentrated H_2SO_4 and 1 g of $HgSO_4$ was added to 20 g of trimethyloctynetriol (I). When the evolution of heat had ceased the reaction mixture was stirred for 75 minutes on the boiling water bath. The products, worked up in the same manner as in the preceding experiment, were vacuum-distilled. The following fractions were isolated: 1st, b. p. 61-62° (2 mm), 0.6 g (3.3%), $n^{20}D$ 1.4528; 2nd, b. p. 110-111° (2 mm), 1.9 g (9.5%), $n^{20}D$ 1.4600; 3rd, b. p. 170-172° (4 mm), 8.5 g (44%), $n^{20}D$ 1.4976. Several more runs were made under the same conditions.

All of the fractions were vacuum-distilled separately. A colorless mobile liquid was isolated from the first fractions, being 2,2-dimethyl-5-sec-butenyltetrahydro-γ-pyrone (IV).

B. p. 61-62° (2 mm), d^{20}_4 0.9495, $n^{20}D$ 1.4528, MR 51.80. $C_{11}H_{18}O_2$ F. Calculated 51.98.

Found %: C 72.64, 72.38; H 9.78, 10.04; OH none. $C_{11}H_{18}O_2$. Calculated %: C 72.52; H 9.89.

A viscous greenish liquid was obtained from the fraction with $n^{20}D$ 1.4600, in all of its constants corresponding to 2,2-dimethyl-5-sec-hydroxybutyltetrahydro-γ-pyrone (V).

B. p. 130-131° (3 mm), d^{20}_4 0.9995, $n^{20}D$ 1.4570, MR 54.49; Calc. 53.98.

Found %: C 66.30, 65.91; H 10.00, 9.96; OH 9.19, 8.90. M 209.6. $C_{11}H_{20}O_3$. Calculated %: C 66.00; H 10.00; OH 8.50. M 209.6.

A quite viscous yellow liquid was isolated from the fraction with b. p. 170-172° (4 mm), which changed readily when stored, and was 2,2-dimethyl-5-sec-butenyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (III).

B. p. 159-160° (3 mm), d^{20}_4 1.021, $n^{20}D$ 1.4983, MR 104.7. $C_{22}H_{36}O_4F_2$. Calculated 103.3.

Found %: C 72.61, 72.88; H 9.95, 9.85; OH 4.92, 5.02. M 381.5, 374.9. $C_{22}H_{36}O_4$. Calculated %: C 72.50; H 9.89; OH 4.67. M 364.

Dehydration of 2,2-dimethyl-5-sec-hydroxybutyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (II) with H_2SO_4 solution (1 : 6). A mixture of 5.0 g of pyranylidenetetrahydropyrone (II) and 28 ml of H_2SO_4 (1 : 6) was stirred for 35 minutes on the boiling water bath (96-98°). The reaction products were worked up in the same manner as in the hydration experiments. Vacuum-distillation gave 3.5 g (73.5 %) of a viscous yellow liquid, being 2,2-dimethyl-5-sec-butenyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (III) with b. p. 145-146° (2 mm), 159-160° (3 mm), and $n^{20}D$ 1.4970.

Action of H_2SO_4 solution (1 : 6) on 2,2-dimethyl-5-sec-butenyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (III). A mixture of 9.3 g of pyranylidenetetrahydropyrone (III) and 70 ml of H_2SO_4 solution was stirred for 2 hours on the boiling water bath. The products were worked up as usual and then vacuum-distilled. The following fractions were collected: 1st, b. p. 90-92° (4 mm), 1.3 g (28.0%), $n^{20}D$ 1.4520; 2nd, b. p. 145-148° (4 mm), 3.2 g (62.7%), $n^{20}D$ 1.4590; 3rd, b. p. 170° (4 mm), 0.5 g.

Redistillation of the 1st fraction gave a clear mobile liquid, being 2,2-dimethyl-5-sec-butenyltetrahydro-γ-pyrone (IV) with b. p. 61-62° (2 mm), and $n^{20}D$ 1.4528.

The liquid isolated from the 2nd fraction was 2,2-dimethyl-5-sec-hydroxybutyltetrahydro-γ-pyrone (V) with b. p. 130-131° (3 mm), and $n^{20}D$ 1.4568.

Oxidation of 2,2-dimethyl-5-sec-butenyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (III) with $KMnO_4$ solution. A solution of 18.2 g of $KMnO_4$ in 450 ml of water, corresponding to 6 atoms of active oxygen per mole of compound, was added dropwise to 10.9 g of (III) in 50 ml of water. Two grams of unoxidized (III) was recovered from the neutral products. In addition, distillation through a column gave 0.3 g of a fraction with b. p. 58-60° and 0.2 g of a fraction with b. p. 72-78°. The 2,4-dinitrophenylhydrazones were prepared from the two fractions which melted respectively at 123-124° and 113-114°, and failed to depress

the melting point when mixed with the dinitrophenylhydrazones of acetone and methyl ethyl ketone, respectively.

It was shown qualitatively that the volatile acids contain formic (formation of mercurous chloride) and acetic (formation of cacodyl oxide) acids. Also, the silver salt of acetic acid was prepared and analyzed. From the nonvolatile acids, we isolated 1.5 g of oxalic acid with m. p. 101-102° (mixed melting point) and 1.5 g of a viscous liquid, the fractional sublimation of which gave small amounts of α-hydroxyisobutyric acid with m. p. 78-79° (mixed melting point) and α-methyl-α-hydroxybutyric acid with m. p. 70-71° (mixed melting point).

Hydrogenation of 2,2-dimethyl-5-sec-hydroxybutyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (II). a) Addition of one mole of hydrogen: 3 g of (II) was hydrogenated over 0.03 g of PtO_2 in 60 ml of CH_3COOH at 696.4 mm and 22° (the catalyst was previously saturated with hydrogen). The hydrogenation was stopped when 210 ml of hydrogen had been absorbed (theory for 2H = 207 ml). The catalyst was filtered, and the product was dissolved in ether. The acetic acid was neutralized with sodium carbonate solution and water. The ether solution was dried, the ether was distilled off, and the product was vacuum-distilled. We isolated 2.6 g (90.2%) of a viscous yellow liquid, which was 2,2'-dimethyl-5-sec-butyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (VI).

B. p. 169-170° (2 mm), d^{20}_4 1.018, $n^{20}D$ 1.4880, MR 103.6. $C_{22}H_{38}O_4F$. Calculated 103.7.

Found %: C 72.36, 72.36; H 10.54, 10.54; OH 4.86, 4.84. $C_{22}H_{38}O_4$. Calculated %: C 72.13; H 10.39; OH 4.64.

b) Addition of two moles of hydrogen: 5 g of (II) was hydrogenated over 0.04 g of PtO_2 in 70 ml of CH_3COOH at 697.3 mm and 22° (the catalyst was previously saturated with hydrogen). The amount of hydrogen absorbed was 690 ml (theory for 4H = 689.4 ml). The product was worked up as before and then vacuum-distilled. We obtained 3.9 g (81%) of a viscous yellow liquid, which, based on the analysis data, was 2,2-dimethyl-5-sec-butyltetrahydropyranyl-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (VII).

B. p. 185-186° (5 mm), d^{20}_4 1.015, $n^{20}D$ 1.4820, MR 103.3; Calc. 104.2.

Found %: C 71.76, 71.55; H 10.70, 10.66; OH 5.10, 5.01. M 378.6, 382.4. $C_{22}H_{40}O_4$. Calculated %: C 71.74; H 10.87; OH 4.62. M 368.

Hydrogenation of 2,2-dimethyl-5-sec-butenyltetrahydropyranylidene-2,2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (III). a) Addition of one mole of hydrogen: 5.4 g of (III) was hydrogenated over 0.03 g of PtO_2 in 60 ml of CH_3COOH at 698.0 mm and 21° (the catalyst was previously saturated with hydrogen). The hydrogenation was stopped when 420 ml of hydrogen had been absorbed (theory for 2H = 389.5 ml). The product was worked up in the usual manner and was vacuum-distilled. We isolated 4.6 g (84.7%) of a viscous liquid, corresponding to 2,2-dimethyl-5-sec-butyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (VI). B. p. 169-170° (2 mm), and $n^{20}D$ 1.4880.

Found %: C 72.43, 72.09; H 10.46, 10.33; OH 4.69, 4.86. $C_{22}H_{38}O_4$. Calculated %: C 72.13; H 10.38; OH 4.64.

b) Addition of two moles of hydrogen: 4.8 g of (III) was hydrogenated over 0.04 g of PtO_2 in 50 ml of CH_3COOH (the catalyst was previously saturated with hydrogen). The amount of hydrogen absorbed was 700 ml (theory for 4H (695.9 mm, 20°) = 692.2 ml). The product, after working up as before, was vacuum-distilled. We obtained 4.5 g (92.7%) of a viscous liquid, which was 2,2-dimethyl-5-sec-butyltetrahydropyranyl-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone (VII) with b. p. 147-148° (1 mm), 185-186° (5 mm), and $n^{20}D$ 1.4820.

Found %: C 71.80, 71.73; H 10.72, 10.88; OH 5.14, 4.79. M 378.7, 368.0. $C_{22}H_{40}O_4$. Calculated %: C 71.74; H 10.87; OH 4.62. M 368.

Hydrogenation of 2,2-dimethyl-5-sec-butenyltetrahydro-γ-pyrone (IV). A solution of 1.3 g of tetrahydropyrone (IV) in 30 ml of acetic acid was hydrogenated over 0.03 g of PtO_2 (the catalyst was previously saturated with hydrogen). The amount of hydrogen absorbed was 280 ml (theory for 2H (689.4 mm, 25°) = 189.1 ml). The product, worked up in the usual manner, was vacuum-distilled. We isolated 1.1 g (83.9%) of a mobile liquid, which based on all of the analytical data, was 2,2-dimethyl-5-sec-butyltetrahydro-γ-pyrone (VIII).

B. p. 97-98° (20 mm), d^{20}_4 0.9264, $n^{20}D$ 1.4398, MR 52.32; Calc. 52.45.

Found %: C 71.85, 71.52; H 11.15, 11.14; OH none. $C_{11}H_{20}O_2$. Calculated %: C 71.73; H 10.87.

2,3,6-Trimethyl-4-octyne-2,3,6-triol (IX)

Hydration of (IX). Triol (X) was prepared by the condensation of dimethylacetylcarbinol with methylethylethynylcarbinol and had the following constants: b. p. 121-122° (1.5 mm), and $n^{20}D$ 1.4799, which corresponds to [5].

a) Ten grams of 2,3,6-trimethyl-4-octyne-2,3,6-triol was hydrated with a mixture of 18 ml of H_2O, 3 ml of H_2SO_4 and 0.5 g of $HgSO_4$. The temperature of the reaction was raised to 80°. The products were worked up in the usual manner. We isolated 4.8 g (50.3%) of a crystalline product and 2.9 g (31.8%) of a liquid.

The crystalline product, after several recrystallizations from petroleum ether, had m. p. 124-125°, and, based on all the data, is 2-methyl-2-ethyl-5-hydroxyisopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (X).

Found %: C 68.85, 69.23; H 10.14, 10.01; OH 8.96, 8.59. M 397.3, 381.7. $C_{22}H_{38}O_5$. Calculated %: C 69.10; H 9.95; OH 8.9. M 382.

The liquid product was vacuum-distilled twice, and is 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxypropyltetrahydro-γ-pyrone (XI).

B. p. 148-149° (2 mm), d^{20}_4 1.016, $n^{20}D$ 1.4903, MR 103.6. $C_{22}H_{36}O_4F_2$. Calculated 103.3.

Found %: C 72.73, 72.38; H 9.91, 9.91; OH 5.09, 5.04. M 345.6, 342.0. $C_{22}H_{36}O_4$. Calculated %: C 72.50; H 9.89; OH 4.67. M 364.

b) A mixture of 41.4 ml of H_2O, 7.68 ml of concentrated H_2SO_4 and 1.29 g of $HgSO_4$ was used to hydrate 25.6 g of trimethyloctynetriol (IX). When the evolution of heat had ceased, the reaction mixture was stirred for 75 minutes on the boiling water bath. The products, worked up as before, were vacuum-distilled. The following fractions were isolated: 1st, b. p. 59-61° (4 mm), 6.0 g (25.7%), $n^{20}D$ 1.4475; 2nd, b. p. 61-66° (4 mm), several drops; 3rd, b. p. 142-143°, 7.5 g (32.2%), $n^{20}D$ 1.4899.

Redistillation of the 1st fraction gave a clear mobile liquid, corresponding to 2-methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone (XII).

B. p. 95-96° (15 mm), d^{20}_4 0.9330, $n^{20}D$ 1.4468, MR 52.11. $C_{11}H_{18}O_2F$. Calculated 51.98.

Found %: C 72.54, 72.56; H 9.83, 9.90; OH none. $C_{11}H_{18}O_2$. Calculated %: C 72.52; H 9.89.

The 3rd fraction, a quite viscous liquid, corresponds to 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XI) with b. p. 148-149° (2 mm), d^{20}_4 1.015, and $n^{20}D$ 1.4903.

Dehydration of 2-methyl-2-ethyl-5-hydroxyisopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (X) with H_2SO_4 solution (1:6). A mixture of 2.5 g of (X) and 12 ml of H_2SO_4 solution (1:6) was stirred for 30 minutes on the boiling water bath (96-97°). The reaction product, worked up in the same manner as the hydration products, was vacuum-distilled. We isolated 1.7 g (72.3%) of a viscous liquid, corresponding to 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XI) with b. p. 171-172° (5 mm), 148-149° (2 mm), and $n^{20}D$ 1.4892.

Found %: OH 4.28. $C_{20}H_{36}O_4$. Calculated %: OH 4.67.

Action of H_2SO_4 solution (1:6) on 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XI). A mixture of 8.4 g of (XI) and 36 ml of H_2SO_4 solution (1:6) was stirred for 75 minutes on the boiling water bath. The products, worked up as usual, were vacuum-distilled. The following fractions were isolated: 1st, b. p. 56-57° (10 mm), 0.8 g (20%), $n^{20}D$ 1.4460; 2nd, b. p. 127-129° (3 mm), 0.2 g, $n^{20}D$ 1.4745; 3rd, b. p. 166-168° (3 mm), 5.5 g, $n^{20}D$ 1.4885.

The 1st fraction was redistilled. The collected product was 2-methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone (XII) with b. p. 95-96° (15 mm), and $n^{20}D$ 1.4468. The 3rd fraction was starting (XI).

Oxidation of 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XI) with $KMnO_4$ solution. A solution of 8.35 g of $KMnO_4$ in 210 ml of H_2O, corresponding to 7 atoms of active oxygen per mole of compound, was added dropwise to 5.0 g of (XI) in 50 ml of H_2O. From the neutral products we isolated 1.4 g of a viscous liquid with b. p. 148-149° (2 mm) and $n^{20}D$ 1.4880, which was starting (XI). In addition, we isolated 0.2 g of acetone (2,4-dinitrophenylhydrazone, m. p. 124-125°, mixed melting point) and 0.4 g of methyl ethyl ketone (2,4-dinitrophenylhydrazone, m. p. 113-114°, mixed melting point).

It was shown qualitatively that the volatile acids (0.79 g) contain formic (mercurous chloride) and acetic (cacodyl oxide) acids. Silver acetate was prepared and analyzed. From the nonvolatile acids, we isolated 0.7 g of oxalic acid with m. p. 101-102° (mixed melting point) and 1.0 g of a mixture of α-hydroxyisobutyric acid, m. p. 78-79° (mixed melting point), and α-methyl-α-hydroxybutyric acid, m. p. 71-72° (mixed melting point), which were separated by fractional sublimation.

Oxidation of 2-methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone (XII) with $KMnO_4$ solution. A solution of 24.1 g of $KMnO_4$ in 600 ml of water, corresponding to 5 atoms of active oxygen per mole of compound, was added dropwise to 7.0 g of (XII) in 50 ml of water. From the neutral products we isolated 0.4 g of methyl ethyl ketone, characterized as the 2,4-dinitrophenylhydrazone with m. p. 114-115° (mixed melting point with authentic specimen).

The volatile acids (2.05 g) were shown to contain formic (mercurous chloride) and acetic (cacodyl oxide, silver salt) acids. From the nonvolatile acids, we isolated 1.0 g of oxalic acid with m. p. 101-102° (mixed melting point) and 1.0 g of α-methyl-α-hydroxybutyric acid with m. p. 71-72° (mixed melting point).

Hydrogenation of 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XI). a) Addition of one mole of hydrogen: 2.9 g of (XI) was hydrogenated over 0.03 g of PtO_2 in 40 ml of CH_3COOH at 693.5 mm and 20° (the catalyst was previously saturated with hydrogen). The hydrogenation was stopped when 210 ml of hydrogen had been absorbed (theory for 2H = 208.9 ml). The product was worked up in the same manner as before, and then was vacuum-distilled. We isolated 2.6 g (89.2%) of a very viscous liquid, corresponding to 2-methyl-2-ethyl-5-isopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XIII).

B. p. 165-166° (4 mm), d^{20}_4 1.0130, $n^{20}D$ 1.4846, MR 103.5. $C_{22}H_{38}O_4F$. Calculated 103.75.

Found %: C 72.19, 72.38; H 10.30, 10.49; OH 4.77, 4.33. $C_{22}H_{38}O_4$. Calculated %: C 72.13; H 10.38; OH 4.64.

b) Addition of two moles of hydrogen: 4.0 g of (XI) was hydrogenated over 0.04 g of PtO_2 in 50 ml of acetic acid at 695.4 mm and 21.5° (the catalyst was previously saturated with hydrogen). The amount of hydrogen absorbed was 590 ml (theory for 4H = 580 ml). The product, worked up as usual, was vacuum-distilled. We obtained 3.2 g (79.1%) of product, corresponding to 2-methyl-2-ethyl-5-isopropyltetrahydropyranyl-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XIV).

B. p. 193-194° (6 mm), d^{20}_4 1.003, $n^{20}D$ 1.4793, MR 104.0; Calc. 104.2.

Found %: C 72.21, 71.83; H 10.71, 10.69; OH 5.43, 4.89. M 371.7, 384.1. $C_{22}H_{40}O_4$. Calculated %: C 71.74; H 10.87; OH 4.62. M 368.

Hydrogenation of 2-methyl-2-ethyl-5-hydroxyisopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (X). a) Addition of one mole of hydrogen: 2 g of (X) was hydrogenated over 0.03 g of PtO_2 in 40 ml of CH_3COOH (the catalyst was previously saturated with hydrogen). The hydrogenation was stopped after the absorption of 160 ml of hydrogen (theory for 2H (693.5 mm, 25°) = 140 ml) and the product, worked up in the usual manner, was vacuum-distilled. We obtained 1.8 g (94.7%) of a viscous liquid, corresponding to 2-methyl-2-ethyl-5-isopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XIII).

B. p. 175-176° (5 mm), 165-166° (4 mm), d^{20}_{4} 1.0120, $n^{20}D$ 1.4842, MR 103.50. $C_{22}H_{38}O_4F$. Calculated 103.75.

Found %: C 72.28, 72.33; H 10.28, 10.29; OH 5.07, 5.23. $C_{22}H_{38}O_4$. Calculated %: C 72.13; H 10.38; OH 4.64.

b) Addition of two moles of hydrogen: 2.0 g of (X) was hydrogenated over 0.03 g of PtO_2 in 40 ml of CH_3COOH at 691.5 mm and 25° (the catalyst was previously saturated with hydrogen). The amount of hydrogen absorbed was 290 ml (theory for 4H = 280.6 ml). The product, worked up as usual, was vacuum-distilled. We isolated 1.65 g (82.5%) of a viscous, slightly yellow liquid, being 2-methyl-2-ethyl-5-isopropyltetrahydropyranyl-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone (XIV).

B. p. 182-183° (3 mm), d^{20}_{4} 1.005, $n^{20}D$ 1.4793, MR 103.9; Calc. 104.2.

Found %: C 71.94, 71.88; H 10.74, 10.87; OH 5.61. $C_{22}H_{40}O_4$. Calculated %: C 71.74; H 10.87; OH 4.62.

Hydrogenation of 2-methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone (XII). A solution of 4.5 g of tetrahydropyrone (XII) in 30 ml of CH_3COOH was hydrogenated over 0.03 g of PtO_2 (the catalyst was previously saturated with hydrogen). The amount of hydrogen absorbed was 680 ml (theory for 2H (693 mm, 22°) = = 656.3 ml). The product, worked up as usual, was vacuum-distilled. We isolated 3.6 g (79.1%) of a mobile liquid, based on all of the data, corresponding to 2-methyl-2-ethyl-5-isopropyltetrahydro-γ-pyrone (XV).

B. p. 89-90° (13 mm), d^{20}_{4} 0.9245, $n^{20}D$ 1.4383, MR 52.28; Calc. 52.45.

Found %: C 71.50, 71.99; H 10.95, 10.92. M 183.3. $C_{11}H_{20}O_2$. Calculated %: C 71.73; H 10.87, M 184.0.

SUMMARY

1. The behavior of two isomeric triols of the acetylene series, 3,4,7-trimethyl-5-octyne-3,4,7-triol and 2,3,6-trimethyl-4-octyne-2,3,6-triol, was examined under the conditions of the Kucherov reaction.

2. It was shown that the reaction products obtained here are 2,2-dimethyl-5-sec-hydroxybutyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone and 2-methyl-2-ethyl-5-hydroxyisopropyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone, respectively.

3. Raising the hydration temperature causes the latter compounds to dehydrate with the formation of 2,2-dimethyl-5-sec-butenyltetrahydropyranylidene-2',2'-dimethyl-5'-sec-hydroxybutyltetrahydro-γ-pyrone and 2-methyl-2-ethyl-5-isopropenyltetrahydropyranylidene-2'-methyl-2'-ethyl-5'-hydroxyisopropyltetrahydro-γ-pyrone, respectively, which under the reaction conditions undergo partial hydrolytic cleavage, the first giving 2,2-dimethyl-5-sec-butenyltetrahydro-γ-pyrone and 2,2-dimethyl-5-sec-hydroxybutyltetrahydro-γ-pyrone, and the second giving 2-methyl-2-ethyl-5-isopropenyltetrahydro-γ-pyrone.

LITERATURE CITED

[1] V. I. Nikitin and A. B. Zegel'man, Zhur. Obshchei Khim. 29, 1898 (1959).*

[2] V. I. Nikitin, A. B. Zegel'man, and A. Kh. Khamatov, Zhur. Obshchei Khim. 29, 1905 (1959).*

[3] S. Veibel, The Identification of Organic Compounds [Russian translation] (Moscow, IL, 1957), p. 57.

[4] V. I. Nikitin and S. D. Savranskaya, Zhur. Obshchei Khim. 23, 1146 (1953).*

[5] V. I. Nikitin and S. D. Savranskaya, Zhur. Obshchei Khim. 25, 1106 (1955).*

* Original Russian pagination. See C. B. translation.

TERTIARY TRIATOMIC ALCOHOLS OF ACETYLENE SERIES AND THEIR TRANSFORMATIONS

XV. HYDRATION OF 5-METHYL-2-(1-HYDROXYCYCLOHEXYL)-3-HEXYNE-2,5-DIOL AND 2,4-BIS (1-HYDROXYCYCLOHEXYL)-3-BUTYN-2-OL

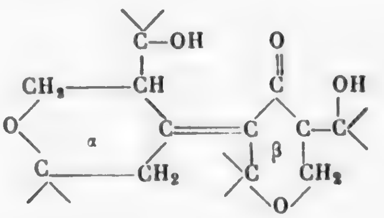
V. I. Nikitin and A. B. Zegel'man

Institute of Chemistry, Academy of Sciences of the Tadzhik.SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 124-127, January, 1960

Original article submitted January 12, 1959

The hydration of some tertiary glycerols of the acetylene series was described in previous communications [1-3]. It was shown that compounds of this type are transformed under the conditions of the Kucherov reaction into compounds of the general formula

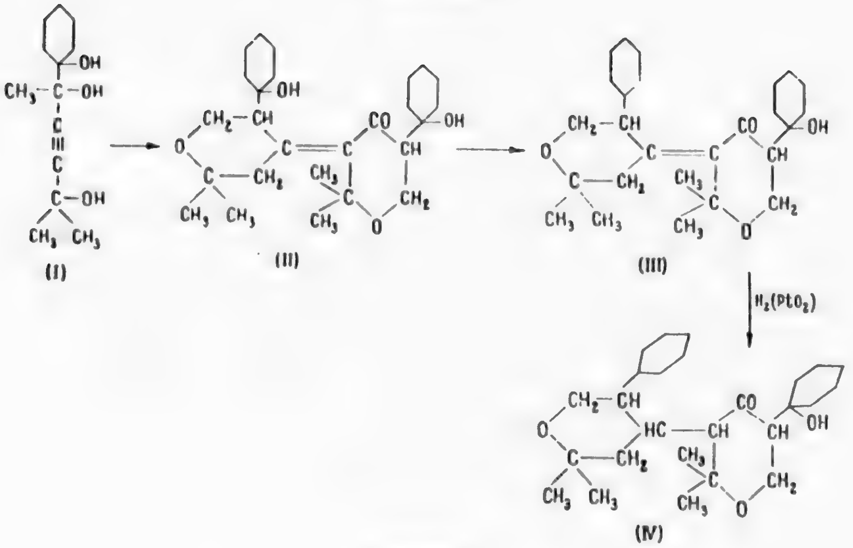


and a possible mechanism was given for the transformation.

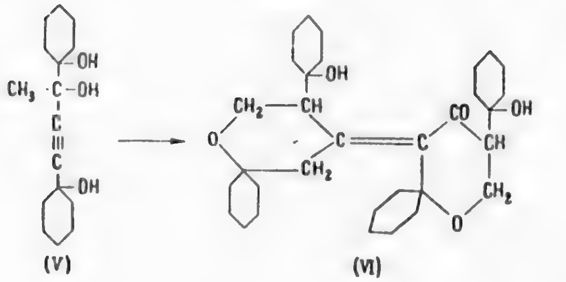
Heating compounds of the indicated general formula with sulfuric acid causes the cleavage of one molecule of water, involving the oxygen found in the (α) ring, and on further heating with sulfuric acid or at a higher temperature there occurs hydrolytic cleavage of the semicyclic double bond into two molecules of substituted tetrahydro-γ-pyrone.

In this paper we present the data obtained by us in the hydration of two new acetylenic glycerols, containing the cyclohexyl radical, namely 5-methyl-2-(1-hydroxycyclohexyl)-3-hexyne-2,5-diol (I) (Scheme 1) and 2,4-bis(1-hydroxycyclohexyl)-3-butyn-2-ol (V) (Scheme 2). Only one reaction product was isolated in each case: the hydration of triol (I) gave 2,2-dimethyl-5-(1-hydroxycyclohexyl) tetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (II), while the hydration of the second triol (V) gave 2-spirocyclohexane-5-(1-hydroxycyclohexyl) tetrahydropyranylidene-2'-spirocyclohexane-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (VI).

Scheme 1



Scheme 2



The structure of these compounds follows by analogy from the earlier investigations [1-3], where it was proved experimentally; the composition was confirmed by the analyses. For (II) we obtained the dinitrophenylhydrazone, which when analyzed for nitrogen also gave an excellent agreement of the found and calculated values.

The hydrogenation of (II) over platinum oxide obeyed the same rule as was observed in all of the previously described cases: it fails to go at all in neutral solvents. In acetic acid solution the hydrogenation with one mole of hydrogen results in the exclusive reduction of one hydroxyl group, leading to the formation of 2,2-dimethyl-5-cyclohexyltetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (III); if hydrogenation is with two moles of hydrogen the double bond, connecting the two rings, is reduced, and 2,2-dimethyl-5-cyclohexyltetrahydropyranyl-2',2'-dimethyl-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (IV) is formed.

Our attempts to hydrogenate (VI) under the same conditions gave negative results, since the hydrogenation of this compound fails to go in neutral solutions, while the compound is insoluble in acetic acid.

EXPERIMENTAL

1. Hydration of 5-Methyl-2-(1-hydroxycyclohexyl)-3-hexyne-2,5-diol (I)

5-Methyl-2-(1-hydroxycyclohexyl)-3-hexyne-2,5-diol (I) (m. p. 87-88°) was obtained as described earlier [4] by the condensation of dimethylethynylcarbinol with acetylcyclohexanol.

5-Methyl-2-(1-hydroxycyclohexyl)-3-hexyne-2,5-diol (I) (31.4 g) was added in portions to a cold mixture of 50 ml of water with 9.5 ml of concentrated H_2SO_4 and 2.1 g of $HgSO_4$. The temperature of the reaction mixture reached 60-70° due to exothermic heat. The reaction product was worked up in the same manner as in

previous cases [1-3]. After several recrystallizations from petroleum ether we isolated 15.5 g (51.3%), of coarse, transparent crystals with m. p. 149-150°, being 2,2-dimethyl-5-(1-hydroxycyclohexyl) tetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (II).

Found %: C 71.63, 71.83; H 9.82, 9.81; OH 7.2, 7.0. M 413.8, 426.4. $C_{28}H_{42}O_5$. Calculated %: C 71.89; H 9.67; OH 7.8. M 434.

2,4-Dinitrophenylhydrazone, m. p. 175-176°.

Found %: N 9.17, 9.13. $C_{32}H_{46}O_8N_4$. Calculated %: N 9.12.

Attempts to dehydrate tetrahydropyrone (II) by heating with different strength sulfuric acid proved unsuccessful, since 15 and 30% H_2SO_4 do not act on (II) at 96-98°, while both 50 and 75% H_2SO_4 char the substance at − 10, 0, and 20°.

Hydrogenation of 2,2-dimethyl-5-(1-hydroxycyclohexyl) tetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (II). a) Addition of one mole of hydrogen. A solution of 5.0 g of (II) in 50 ml of acetic acid was hydrogenated over 0.04 g of PtO_2 (the catalyst was previously saturated with hydrogen). The hydrogenation was stopped when 283.5 ml (theory for 2H = 261 ml at 688.5 mm and 30°) of hydrogen had been absorbed. The product was worked up as in previous cases [1-3]. A Favorskii flask with a Vigreux column was used for the vacuum-distillation, since the compound was a viscous liquid with a very low vapor pressure. We collected 4.0 g (81.6%) of a viscous, slightly yellow liquid, which immediately congealed to a glass, and was 2,2-dimethyl-5-cyclohexyltetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl)tetrahydro-γ-pyrone (III).

B. p. 198-199° (1 mm), $n^{20}D$ 1.5133, MR_D 116.6. $C_{26}H_{42}O_4F$. Calculated 117.8.*

Found %: C 74.98, 74.34; H , 9.97; OH 3.92, 4.34.

b) Addition of two moles of hydrogen. A solution of 3.0 g of (II) in 30 ml of acetic acid was hydrogenated over 0.02 g of PtO_2 (the catalyst was previously saturated with hydrogen). The amount of hydrogen absorbed at 695.4 mm and 14° was 350 ml. Theory is 298.6 ml (4H). The product, worked up in the usual manner, was vacuum-distilled. We isolated 2.4 g (80.0%) of a clear, very viscous liquid, which congealed to a glass, and was 2,2-dimethyl-5-cyclohexyltetrahydropyranyl-2',2'-dimethyl-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (IV).

B. p. 200-202° (2 mm), n^{20} 1.5034, MR_D 117.1 (determined from [5]); Calc. 118.3.

Found %: C 74.07, 74.29; H 10.35, 10.25; OH 5.07, 4.61. M 396.2, 433.6. $C_{26}H_{44}O_4$. Calculated %: C 74.28; H 10.49; OH 4.07. M 420.0.

2. Hydration of 2,4-bis(1-hydroxycyclohexyl)-3-butyn-2-ol (V)

2,4-Bis(1-hydroxycyclohexyl)-3-butyn-2-ol (V) (m. p. 107-108°) was prepared by the condensation of ethynylcyclohexanol with acetylcyclohexanol [4].

Ten grams of 2,4-bis(1-hydroxycyclohexyl)-3-butyn-2-ol was added in portions to a homogeneous solution of 27.3 ml of H_2O, 5.3 ml of concentrated H_2SO_4 and 1.0 g of $HgSO_4$. After adding all of the triol, the reaction mixture was heated on the boiling water bath for 1 hour. The product was worked up the same as before [1-3]. After several recrystallizations from a mixture of benzene and petroleum ether we obtained 5.2 g (53.8%) of transparent crystals, being 2-spirocyclohexane-5-(1-hydroxycyclohexyl) tetrahydropyranylidene-2'-spirocyclohexane-5'-(1-hydroxycyclohexyl) tetrahydro-γ-pyrone (VI).

Found %: C 74.85, 74.56; H 10.13, 9.90; OH 7.03, 6.95. M 505.6. $C_{32}H_{50}O_5$. Calculated %: C 74.71; H 9.72; OH 6.61. M 5.14.

We were unable to obtain either the 2,4-dinitrophenylhydrazone or the semicarbazone of the compound.

* Since the specific gravity of the product could not be determined, we determined the molecular refraction in solution [5], using dioxane as the solvent.

SUMMARY

1. The tertiary glycerols of the acetylene series, 5-methyl-2-(1-hydroxycyclohexyl)-3-hexyne-2,5-diol and 2,4-bis(1-hydroxycyclohexyl)-3-butyn-2-ol, were hydrated by the Kucherov procedure.

2. Similar to previously obtained results, hydration of the indicated triols gave 2,2-dimethyl-5-(1-hydroxycyclohexyl)tetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl)tetrahydro-γ-pyrone and 2-spirocyclohexane-5-(1-hydroxycyclohexyl)tetrahydropyranylidene-2'-spirocyclohexane-5'-(1-hydroxycyclohexyl)-tetrahydro-γ-pyrone, respectively.

3. The same as in all of the previous cases examined, the reduction of 2,2-dimethyl-5-(1-hydroxycyclohexyl)tetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl)tetrahydro-γ-pyrone in acetic acid solution over platinum oxide goes in such manner that the first mole of hydrogen selectively reduces the hydroxyl group in the tetrahydropyranylidene ring, forming 2,2-dimethyl-5-cyclohexyltetrahydropyranylidene-2',2'-dimethyl-5'-(1-hydroxycyclohexyl)tetrahydro-γ-pyrone. The second mole of hydrogen reduces the double bond in the molecule, forming 2,2-dimethyl-5-cyclohexyltetrahydropyranyl-2',2'-dimethyl-5'-(1-hydroxycyclohexyl)-tetrahydro-γ-pyrone.

4. 2-Spirocyclohexane-5-(1-hydroxycyclohexyl)tetrahydropyranylidene-2'-spirocyclohexane-5'-(1-hydroxycyclohexyl)tetrahydro-γ-pyrone is not hydrogenated over platinum oxide in neutral solvents, and is insoluble in acetic acid.

LITERATURE CITED

[1] V. I. Nikitin and A. B. Zegel'man, Zhur. Obshchei Kh[illegible] 29, 1898 (1959).*

[2] V. I. Nikitin, A. B. Zegel'man, and A. Kh. Khamatov, [illegible]ur. Obshchei Khim. 29, 1905 (1959).*

[3] V. I. Nikitin and A. B. Zegel'man, Zhur. Obshchei Khim. 30, 115 (1950).*

[4] V. I. Nikitin and S. D. Savranskaya, Zhur. Obshchei Khim. 23, 1146 (1953).*

[5] A. E. Chichibabin, Principles of Organic Chemistry [In Russian], Vol. I, p. 471 (1953).

* Original Russian pagination. See C. B. translation.

HYDROGENATION OF 1,4-POLYBUTADIENE AT ATMOSPHERIC PRESSURE

A. I. Yakubchik and B. I. Tikhomirov

Leningrad State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 128-132, January, 1960

Original article submitted January 19, 1959

An investigation of the hydrogenation of polybutadiene has both theoretical and practical importance.

1) The hydrogenation of 1,4-polybutadiene opens a route to obtaining a series of products with a variable degree of unsaturation and containing different types of double bonds. A comparison of the chemical and physical properties of substances linked genetically and having common structural elements makes it possible to arrive at more complete conclusions regarding the relationship between the properties of molecules and their structure than if the discussion is limited only to one substance [1].

2) A study of the various transformations of macromolecules with reactive groups as a means of obtaining polymers which cannot be synthesized by polymerization and polycondensation techniques [2, 3] begins to assume constantly increasing importance in the contemporary chemistry of polymers. An examination of the peculiarities of the hydrogenation of 1,4-polybutadiene when compared with that of low-molecular substances containing the same type of double bond, might be beneficial in studying other heterogeneous catalytic reactions of polymers.

3) The hydrogenation products of emulsion-polymerized polybutadiene find practical utility [4-7].

The hydrogenation of 1,4-polybutadiene represents a quite complex case of the hydrogenation of bivinyl polymers, since, first, disubstituted symmetrical ethylene derivatives add hydrogen with greater difficulty than do the monosubstituted, and second, the appearance of segments of regular structure in the macromolecules of the hydrogenated rubber facilitates crystallization and decreases the solubility of the polymer.

The purpose of the present paper was to study the hydrogenation of linear 1,4-polybutadiene at atmospheric pressure. The results of high-pressure hydrogenation, and also the properties of the obtained products, will be described later. For profound hydrogenation to take place, it is first of all necessary that both the starting material and the reaction products remain in solution. In its structure the product of the complete hydrogenation of linear 1,4-polybutadiene should be analogous to high density polyethylene whose degree of crystallinity reaches 85% [8]. Crystalline polymers are rather difficultly soluble.

From theoretical considerations the convergence temperature for hydrocarbons with linear chains was calculated to be 137° [9], which is in agreement with the existing experimental data [8]. In the fractionation of high density polyethylene [10] it is known that a higher molecular weight fraction begins to precipitate if the polyethylene solutions are cooled to 133-130°. From these considerations, it follows that temperatures below 140° can hardly be used to obtain a high degree of hydrogenation. Consequently, if, as a rule, temperatures not exceeding 100° (when operating with catalysts prepared from the noble metals) are used for the addition of hydrogen to low-molecular disubstituted symmetrical ethylene derivatives, then for polybutadiene of the indicated structure this temperature range is not suitable. It is obvious from this that the solvent should have a

quite high boiling point. Experimental study of the hydrogenation confirmed the need of using high temperatures (not below 140°) and a solvent with a high boiling point (decalin) to obtain a high degree of hydrogenation. It was also shown that it is expedient to use a catalyst deposited on a carrier.

EXPERIMENTAL

We took soluble linear 1,4-polybutadiene for the experiments. The rubber was freed of impurities by a double reprecipitation from 1% benzene (thiophene-free) solution with alcohol. The same as in previous studies [11, 12], it was shown that rather than use nitrogen to protect the polymer from atmospheric oxygen, it is more practical to use an antioxidant; in the second reprecipitation we added 1 wt. % of Neozone D to the polymer. After precipitation, the rubber was dried to constant weight at 20-25° and a residual pressure of 1-2 mm. The purification of the rubber was done in an atmosphere of oxygen-free nitrogen [13]. The unsaturation of the investigated polymer, determined using iodine bromide solution [14], was 94.2%.

We selected decalin as the solvent. It dissolves both the starting polymer and the reaction products, has a high boiling point, does not hydrogenate, does not poison catalysts, and is stable nearly up to the boiling point. In addition, according to Staudinger [15], polyethylene can be dissolved in decalin without association. This made it possible to assume that hydrorubbers would also fail to give undesirable associates in this solvent. It is obvious that more complete contact will be achieved between the separate macromolecules and the catalyst than when the macromolecules are found in an associated state. After purification [16], the decalin was hydrogenated using platinum black [17] until all of the unsaturated impurities were removed completely.

The following catalysts were used to hydrogenate the rubber, dissolved in decalin: palladium black [18], palladium deposited on calcium carbonate [19], skeletal nickel [20], and platinum black [17]. Platinum black was in no way superior to palladium black. The hydrogen for the hydrogenations was obtained by the electrolysis of 30% sodium hydroxide solution. The hydrogenations were run using the S. V. Lebedev apparatus [21], in a glass vessel fitted with an asbestos-insulated "jacket." Using an I-8 thermostat, glycerol was passed through the jacket at the desired temperature and a rate of 7 liters/min. The amount of hydrogen absorbed was read every 2 min. The reading accuracy was ± 0.25 ml. Even in those cases where the hydrorubber remains in solution, it was found that the hydrogenation rate curve decreases with time from the very start of reaction (Fig. 1), thus differing from the curves for the hydrogenation of low-molecular disubstituted symmetrical ethylene derivatives, which add at least 50% of the theoretical hydrogen at a constant rate. A decrease in the hydrogenation rate can be explained only by the difficulty of adding hydrogen to the double bonds in the partially hydrogenated rubber. As a result, a descending character of the curve is linked with the high-molecular nature of the material being hydrogenated.

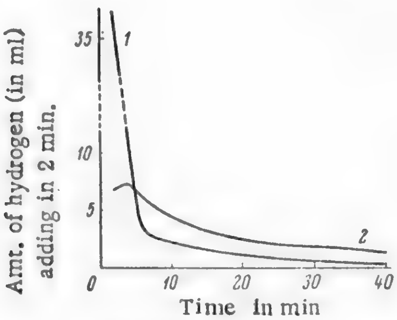


Fig. 1. Hydrogenation rate curves. 1) On palladium, deposited on calcium carbonate (Expt. 12); 2) on palladium black (Expt. 7).

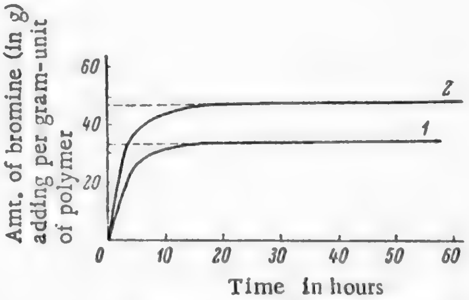


Fig. 2. Curves for the bromination of hydropolybutadienes. 1) Obtained in Expt. 12; 2) obtained in Expt. 7.

Hydrogenation on palladium black (Table, Expts. 5-9) revealed that when the amount of rubber in solution is increased, the degree of hydrogenation remains constant only if the weight ratio of catalyst to rubber is kept constant. From this, it is clear why a catalyst with a developed surface, such as palladium deposited on calcium

carbonate, gives better results (Expt. 12) than does palladium black. However, a further increase in the amount of catalyst no longer leads to an increase in the degree of hydrogenation (Expt. 13). The use of catalysts with a developed surface is also desirable for the reason that it permits a more rapid transition from the starting polymer to the products of the desired degree of reduction, and thus avoids possible changes in the rubber during heating. Polybutadiene cannot be hydrogenated on skeletal nickel without first removing the alcohol with which the catalyst is saturated. It is quite probable that the alcohol coating makes it difficult for the polymer molecules to come in contact with the catalyst surface. Polybutadiene hydrogenates on skeletal nickel only after the catalyst has been thoroughly washed five times with pentane, free of unsaturated compounds. It was found that polar impurities exert a negative influence on the hydrogenation efficiency of the catalysts. Thus, the addition of 0.5 ml of acetone to 100 ml of a 0.5% solution of the rubber in decalin reduces the hydrogenation activity of platinum black with respect to the polymer to zero, whereas the acetone itself is hydrogenated.

On conclusion of hydrogenation, the catalyst was removed by centrifuging the hot solution for 2-3 minutes at 1500 rpm. Since during centrifuging a part of the hydrorubber deposited together with the catalyst because of a reduction in the solution temperature, the catalyst deposit was treated with hot decalin and the centrifuging repeated. Then to isolate the reaction product the hydrorubber solution was poured into acetone containing Neozone D. Here the hydrorubber deposited as light flocs. The precipitate was condensed by centrifuging at 3000 rpm, washed well with acetone, and dried to constant weight at 1-2 mm and 35-40°.

Effect of Conditions on the Degree of 1,4-Polybutadiene Hydrogenation

Expt. No.	Catalyst	Solution conc. (in %)	Rubber : :catalyst ratio	Temp.	Amt. of hydrogen added (in %)	Unsaturation (in %)
1	Palladium black	0.1	1 : 1	100°	12.5	85.7
2		0.1	1 : 1	120	19.8	78.6
3		0.1	1 : 1	140	43.8	54.8
4		0.1	1 : 1	160	38.2	59.1
5		0.3	3 : 1	140	34.5	65.0
6		0.3	1 : 1	140	68.9	29.4
7		0.5	1 : 1	140	68.6	30.4
8		0.7	1 : 1	140	69.9	29.1
9		1.0	1 : 1	140	67.3	28.4
10		1.5	1 : 1	140	61.5	35.2
11		0.3	1 : 1	180	33.6	56.8
12	Palladium on $CaCO_3$	0.5	1 : 2	140	75.4	22.5
13		0.5	1 : 10	140	76.7	22.8
14	Skeletal nickel	0.5	1 : 2	140	42.0	56.3

The unsaturation of both the starting and hydrogenated polymers was determined. However, only the starting rubber and the products with a high unsaturation, obtained in Expts. 1 and 2, proved to be soluble at room temperature. In their case, the unsaturation was determined using iodine bromide solution [14]. For the samples insoluble at room temperature, we determined the unsaturation using the bromine addition technique [22]. For this the hydrorubber (10-20 mg) was kept in bromine vapors for successively increasing lengths of time. After each bromination the excess bromine was removed by suction from the hydrorubber sample to constant weight in order to determine the amount of added bromine.

Bromination curves expressing the relation between the amount of bromine adding to a gram-unit of the polymer, and the bromination time, are shown in Fig. 2. The bromination was continued until the curves for the addition of bromine became linear. The curves always show some rise relative to the time axis due to substitution reactions. Extrapolation of the linear portion of the curve to zero time gives the amount of bromine added. It is very important that the bromination be run in the complete absence of light, since, even a short exposure to light enhances substitution reactions. The use of this method to determine the unsaturation of irradiated polyethylene gave results that show good agreement with infrared analysis data [23]. Application

of the bromination method to the starting polymer and the highly unsaturated hydrogenation products (Expts. 1 and 2) gave clearly high results, which, in contrast to the subsequent experiments (Expts. 3-14), fail to agree with the amount of hydrogen added.

The authors wish to thank V. A. Krol for graciously supplying the 1,4-polybutadiene samples.

SUMMARY

1. A study of the hydrogenation of linear 1,4-polybutadiene in decalin at atmospheric pressure revealed that products with the least unsaturation are obtained if the hydrogenation is run on palladium deposited on calcium carbonate at a temperature not below 140°.

2. It was shown that it is possible to determine the unsaturation of hydropolybutadienes insoluble at room temperature by using bromine vapors.

LITERATURE CITED

[1] State of the Theory of Chemical Structure in Organic Chemistry [In Russian] (1954), p. 63.

[2] W. Kern and R. G. Schulz, Angew. Chem. 69, 153 (1957).

[3] J. A. Blanchette and J. D. Cotman, Jr., J. Org. Chem. 23, 1117 (1958).

[4] U. S. Patent 2,731,439 (1956).

[5] U. S. Patent 2,813,809 (1957).

[6] H. Peters and W. Lockwood, Rubber World 138, 3, 418 (1958).

[7] D. Wright and N. Parkman, Brit. Plast. 31, 255 (1958).

[8] Chem. Eng. News. 36, 29, 56 (1958).

[9] H. Mark, J. Appl. Phys. 12, 41 (1941).

[10] S. L. Aggarwal and O. J. Sweeting, Uspekhi Khim. 27, 1147 (1958) [Publisher: apparently, a translation of the article published in Chem. Revs. 57, 665 (1957)].

[11] A. I. Yakubchik and G. N. Gromova, Zhur. Obshchei Khim. 26, 1381 (1956).*

[12] R. V. Jones, C. W. Moberly, and W. B. Reynolds, Ind. Eng. Chem. 45, 1117 (1953).

[13] K. Uhrig, F. M. Roberts, and H. Levin, Ind. Eng. Chem., Anal. Ed. 17, 31 (1945).

[14] A. A. Vasil'ev, Zhur. Obshchei Khim. 17, 923 (1947).

[15] H. Staudinger, Ang. Chem. 64, 155 (1952).

[16] A. Weissberger, Technique of organic chemistry, Vol. VII, Organic Solvents 313 (1955).

[17] O. Loew, Ber. 23, 289 (1890).

[18] J. Tausz and N. Putnoky, Ber. 52, 1576 (1919).

[19] M. Busch and K. Schulz, Ber. 62, 1458 (1929).

[20] H. Adkins and H. Billica, J. Am. Chem. Soc. 70, 695 (1948).

* Original Russian pagination. See C. B. translation.

[21] S. V. Lebedev, G. G. Koblyanskii, and A. I. Yakubchik, Zhur. Russ. Khim. Obshchestva 56, 265 (1924).

[22] E. Rossmann, Ber. 65, 1847 (1932).

[23] M. Dole, C. D. Keeling, and D. G. Rose, J. Am. Chem. Soc. 76, 4305 (1954).

MECHANISM OF DEHYDRATION OF γ-GLYCOLS

VII. REACTIVITY OF ACETYLENIC HYDROGEN OF HYDROXY-SUBSTITUTED OXYGEN-CONTAINING ACETYLENE DERIVATIVES

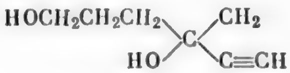
T. A. Favorskaya and O. V. Sergievskaya

Leningrad State University

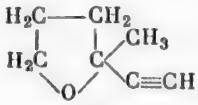
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 132-134, January, 1960

Original article submitted September 15, 1958

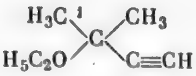
The earlier described [1] compounds (I - IV) show a quite different lability of the acetylenic hydrogen in the formation of acetylide with ammoniacal silver nitrate solution.



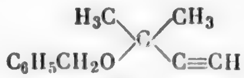
(I)



(II)



(III)



(IV)

Thus, it was observed that 3-methyl-1-hexyne-3,6-diol (I) forms the acetylide only when boiled with the indicated reagent, whereas its dehydration product, 2,2-dimethylethynyltetrahydrofuran (II), rapidly gives the acetylide at room temperature, although its solubility in the reagent is lower than that of diol (I). The ethyl ether of dimethylethynylcarbinol (III) rapidly gives the acetylide at room temperature, but the benzyl ether (IV) of the same alcohol fails to form the acetylide even on long boiling (the latter also fails to form a characteristic precipitate with mercuric chloride).

This caused us to seek an explanation for the indicated phenomenon, which led to making the present study. It seemed to us that the reduced activity of compounds (I) and (IV) might be due to the possible formation of intermolecular hydrogen bonds involving the acetylenic hydrogen (intramolecular reaction is impossible in the given case because of steric factors).

That it is possible to form a hydrogen bond between the hydrogen of the $\equiv C-H$ group and the electronegative atom of the solvent, having an unshared electron pair, was indicated in [2] when studying the solubility and heats of mixing of acetylene and phenylacetylene with various organic solvents.

$$\equiv C-H \;.\;.\;.\;.\;.\;.\; X, \text{where } X = :O<, \; :N\lessgtr$$

Actually, it was established by infrared spectroscopy [3] that the more basic the character of Y, the more stable is the hydrogen bond, i.e., the greater the shift of the absorption band of the $\equiv C-H$ group.

Taking into account the peculiarities of the chemical structure of acetylene and its derivatives, it was experimentally shown [4] that these compounds can form, both with each other and with solvent molecules, complexes of the type $\equiv C-H.....X$ where $X = :O<$, $O=C<$, $:N\lessgtr$, $-C\equiv C-$ by hydrogen bonding.

The high protonization of the hydrogen atom attached to the acetylenic bond is responsible for the great ease with which it is replaced by metal. In the event of intermolecular reaction between the hydrogen of the $\equiv C^{-\delta}-H^{+\delta}$ group and the unshared electron pair of the oxygen atom $:O<$, or the π-electrons of the triple bond of adjacent molecules, it is possible for the positive charge on the hydrogen atom to be partially neutralized, i.e., for its acidity to be reduced. A reduction in the positive charge on the hydrogen atom should possibly be reflected in the ease and rate with which the acetylide is formed.

We made an attempt to compare the data on the different reactivity of the acetylenic hydrogen with the magnitude of the shift in the absorption band of the $\equiv C-H$ group in the infrared region.*

One (3290 cm^{-1}) or two broad, strongly overlapping, absorption bands (3260 and 3310 cm^{-1}) correspond to the absorption of the indicated group in the monoacetylenes examined by us in the liquid state.

Compound	ν (in cm^{-1}) pure substance	ν (in cm^{-1}) 1% CCl_4 solution	$\Delta\nu$
(I)	3290 (b)	3315 (n)	25
(II)	3260 (b) 3295 (b)	3315 (n)	55 20
(III)	3260 (b) 3310 (b)	3315 (n)	55 * 5
(IV)	3295 (b)	3310 (n)	15

* The Raman spectrum of this compound gives a shift to 26 cm^{-1} [5].

Judging by the magnitude of the shift of the valence vibration band of the $\equiv C-$ group, an extremely slight participation of the $\equiv C-H$ group in intermolecular reaction is observed for (I) and (IV), while (II) and (III) show a quite strong intermolecular reaction between the hydrogen of this group and the unshared electron pair of the oxygen atom of the adjacent molecule, although both (II) and (III) have a quite labile acetylenic hydrogen, which is easily replaced by metal.

It is possible that proton magnetic resonance spectra, which are extremely sensitive to hydrogen bond formation [6], may give more definite results.

SUMMARY

1. It was established that the magnitude of the intermolecular reaction between the hydrogen of the $\equiv CH$ group and the unshared electron pair of the oxygen atom of the adjacent molecule is clearly not related to the rate with which the acetylide is formed in the reaction with ammoniacal silver oxide solution.

* The spectra were taken by E. V. Shuvalova in the laboratory of V. M. Chulanovskii.

2. It was shown that the method of infrared spectroscopy is inadequate in studying the lability of acetylenic hydrogen.

LITERATURE CITED

[1] T. A. Favorskaya and O. V. Sergievskaya, Zhur. Obshchei Khim. 28, 3232 (1958).*

[2] M. J. Copley and C. E. Holley, J. Am. Chem. Soc. 61, 1599 (1939).

[3] S. C. Stanford and W. Gordy, J. Am. Chem. Soc. 63, 1094 (1941).

[4] D. N. Shigorin, M. M. Shemyakin, and M. N. Kolosov, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk (1958), 1134.*

[5] Kim. Den Dok, De En Uk, and Khan Don Sen, Matematika i Fizika, Pkhen'yan, AN KNDR 1, 79 (1958).

[6] I. V. Aleksandrov and N. D. Sokolov, Doklady Akad. Nauk SSSR 124, 115 (1959).*

* Original Russian pagination. See C. B. translation.

DIMERIZATION OF CHLOROPRENE

I. N. Nazarov and A. I. Kuznetsova

Institute of Organic Chemistry, Academy of Sciences of the USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 134-138, January, 1960

Original article submitted January 15, 1959

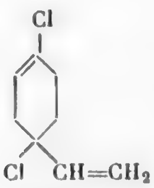
We had shown [1] that the dimerization of isoprene at temperatures from 100-290° is accompanied by the formation of all of the theoretically possible six-membered and eight-membered dimers, in which connection their proportions are strongly dependent on the temperature. The reaction temperature (140-200°) is essentially without effect on the dimerization of piperylene [2].

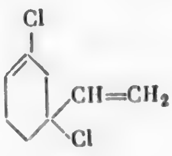
It seemed of interest to make a detailed study of the dimerization of still another diene, namely chloroprene, which had been partially studied earlier.

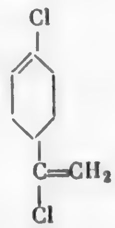
The ability of chloroprene to dimerize was first noted by Carothers and co-workers [3], after which it was studied further by a number of authors. In studying the residues remaining in the distillation pot after distilling off the chloroprene [4], two fractions were isolated, and it was shown by hydrogenation and ozonization that the first fraction contains the six-membered, while the second fraction contains the eight-membered cyclic dimers. It was established by A. L. Klebanskii and M. M. Denisova [5] that the mixture formed in the dimerization of chloroprene at 65° contains the six-membered dimers (I) and (III), with substituents in the para position. The dimerization of chloroprene at 80° [6] gave an eight-membered dimer in 20% yield, but its structure was not established. Finally, when this reaction was run in xylene solution at 60-85° [7], it was shown by ozonization that the fraction containing the eight-membered dimers is chiefly dimer (V).

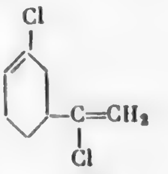
As a result, of the four six-membered (I - IV) and two eight-membered (V, VI) dimers theoretically possible in a mixture of chloroprene dimers only the presence of two six-membered isomers (I) and (III), with substituents in the para position, and one eight-membered dimer (V) has been shown up to now.

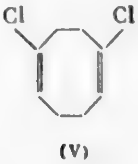
None of the mentioned authors studied the products obtained in the dimerization of chloroprene at 15-20°.

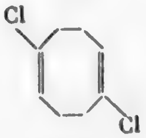

(I)


(II)


(III)


(IV)

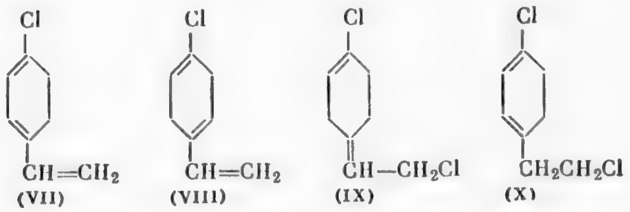

(V)


(VI)

We were able to show that chloroprene undergoes 45% conversion to a mixture of dimers when it is stored in the presence of pyrogallol for more than two years. Investigation of a mixture of chloroprene dimers is a difficult task because of the instability of the products formed and the difficulty of converting them to known compounds for proof of structure.

The same as in the case of the isoprene dimers, vacuum-distillation of the mixture of chloroprene dimers, formed at 15-20°, through a column filled with glass packing yields three main fractions in the approximate proportions: first 30%, second 40%, and third 6-8%. Fractional distillation of the chloroprene dimerization products is always accompanied by the formation of a small head fraction, which apparently consists of traces of chloroprene, a mixture of dimers (I) and (II), and their HCl-cleavage products.

Investigation of the low-boiling fraction (b. p. 63-64.5° at 2 mm, $n^{20}D$ 1.5115), apparently composed mainly of a mixture of dimers (I) and (II), is made difficult because of the instability of these compounds. As is known [5], dimer (I) can easily cleave hydrogen chloride with the formation of trienes (VII) or (VIII).

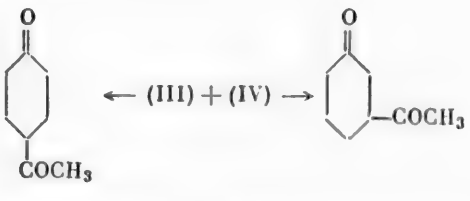


Also not excluded is migration of the chloride to allylic position and the formation of products of type (IX) and (X).

Having effected the dehydrochlorination of this fraction by passage over barium chloride deposited on carbon, or its dehydrogenation over palladium-on-carbon, we obtained a liquid product, which when oxidized with chromium trioxide in acetic acid gave p-chlorobenzoic acid in a total yield of 27%,* which indicates that this fraction contains dimer (I). We were unable to isolate any m-chlorobenzoic acid corresponding to dimer (II) from the oxidation mixture.

The use of other methods to prove the structure of the low-boiling fraction, for example, dehydrogenation by reaction with bromosuccinimide and then dehydrohalogenation and oxidation, and also hydrolysis using sulfuric acid, led only to the formation of polymeric products.

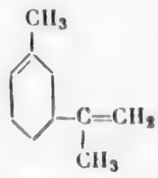
The middle fraction (b. p. 73.5-74.5° at 2 mm, $n^{20}D$ 1.5180), containing dimers (III) and (IV), when hydrolyzed with concentrated sulfuric acid gave a liquid mixture of 3- and 4-acetylcyclohexanone.



Crystalline 3-acetylcyclohexanone was isolated in 40% yield from this mixture by freezing, while the 4-acetylcyclohexanone was isolated from the mother liquor as the dioxime in 30% yield. As a result, the structure of dimers (III) and (IV) and their presence in the dimerization products was established conclusively.

* As is known [7], separation of this mixture of dimers as the pyridine salt and its subsequent oxidation with potassium permanganate gave p-chlorobenzoic acid in a yield of only 2.3 %.

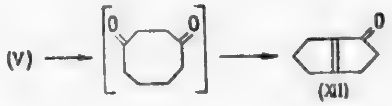
It is interesting that, the same as in the dimerization of isoprene at low temperature, the formation of the meta-isomer (IV) is also observed in this case, the presence of which in the dimerization products could not be established earlier [5, 7]. The m-dimer (IV) is apparently formed in a somewhat larger amount than the para-isomer (III), and consequently, the earlier mentioned fact [1] that the meta-isomer (XI) is formed predominantly in the low-temperature dimerization of isoprene does not stand alone.



(XI)

We were unable to dimerize chloroprene at elevated temperature (200-300°). Heating chloroprene in toluene solution in an autoclave at 150°, in the presence of pyrogallol and a nitrogen atmosphere, resulted in the cleavage of hydrogen chloride and the formation of tarry products, accompanied by much heat evolution and increase in pressure. It is possible to assume that hydrogen chloride is formed here either as the result of cleavage from the formed mixture of dimers (I) and (II), or due to decomposition of the chloroprene itself.

The low-temperature dimerization of chloroprene is also accompanied by the formation of the eight-membered dimer (V), which proved to be the main product in the third fraction (b. p. 77.5-85.5° at 0.5 mm, $n^{20}D$ 1.5350). Hydrolysis of this fraction with concentrated sulfuric acid [7] gave the bicyclic ketone (XII), characterized as the semicarbazone.



In this case, our results coincided with the conclusions of previous authors who studied the dimerization of chloroprene at elevated temperatures (65-85°).

EXPERIMENTAL

Dimerization of chloroprene at 15-20°. The chloroprene (3140 g) was kept in a flask with sealed stopper, in the presence of 3% pyrogallol, in the dark, at 15-20°, for 2 years. The thus obtained mixture of products was distilled in 100 g portions. The unreacted chloroprene was vacuum-distilled on the water bath at 20-25 mm and 30-40°, and was collected in a trap, immersed in a cooling mixture (−60 to −70°). Then the mixture of chloroprene dimers with b. p. 70-90° (5 mm) (bath temperature not above 150°) was distilled from the residue. The total amount of unreacted chloroprene was 1285 g (40%), while the mixture of chloroprene dimers weighed 1430 g (45%), and the residue weighed 420 g.

The mixture of dimers was vacuum-distilled in 100 ml* portions through a column filled with glass packing and having an efficiency of 23 theoretical plates. The fractional distillation of 116 g (100 ml) of this mixture gave roughly the following fractions: 1st, 44-63° (2 mm), $n^{20}D$ 1.5107, 8 g (7%); 2nd, 63-64.5° (2 mm), $n^{20}D$ 1.5115, 32 g (28%); 3rd, 65-73.5° (2 mm), $n^{20}D$ 1.5135, 11.2 g (10%); 4th, 73.5-74.5° (2 mm), $n^{20}D$ 1.5180, 38 g (32%); 5th, 75-90° (2 mm), $n^{20}D$ 1.5279, 7.7 g (7%); residue, 19 g (17%). The same

* Decomposition of the product, apparently of dimers (I) and (II), was observed when larger amounts (300 g) were distilled, with the copious evolution of hydrogen chloride, and we were able to isolate only fractions containing dimers (III, IV, and V) when the resulting complex mixture was distilled.

fractions from the separate portions were combined. A mixture of 111.5 g of combined 5th fractions X and the residues from five experiments; X was also distilled through the same column. Here, we obtained 36.5 g of product corresponding to the 4th fraction, with b. p. 55.5° (0.5 mm) and $n^{20}D$ 1.5180, and 31.6 g of a product with b. p. 77.5-85.5° (0.5 mm), and $n^{20}D$ 1.5350, composed mainly of eight-membered dimers.

Investigation of the low-boiling fraction. The fraction with b. p. 63-64.5° (2 mm) and $n^{20}D$ 1.5115 is apparently a mixture of the chloroprene dimers, 4-vinyl-1,4-dichlorocyclohexene (I) and 3-vinyl-1,3-vinyl-1,3-dichlorocyclohexene (II), and their transformation products.

Found %: C 54.95; H 5.94; Cl 38.80. $C_8H_{10}Cl_2$. Calculated %: C 54.26; H 5.69; Cl 40.05.

The dehydrogenation and dehydrochlorination of this fraction was accomplished in the vapor phase by passing the substance at a rate of 2-3 drops per minute through a vertical glass tube 8 mm in diameter, filled with the catalyst and heated in an electric furnace. Six grams of the substance was passed over 10 ml of 15% palladium-on-carbon in a nitrogen stream at 325°. The copious evolution of hydrogen chloride was observed here. As reaction result, we obtained 4.33 g of condensate ($n^{20}D$ 1.5149), which was then oxidized with a solution of 27 g of chromium trioxide in 170 ml of 50% acetic acid and 22 ml of concentrated sulfuric acid under reflux for 1 hour. The resulting p-chlorobenzoic acid was filtered, washed with water, and dried; we obtained 1.1 g of acid with m. p. 242-243° (yield 20% on the two steps). The mixed melting point with an authentic specimen was not depressed.

Six grams of the same fraction was dehydrochlorinated over 8 ml of 10% barium chloride-on-carbon at 270-290° in a nitrogen stream. The obtained condensate (4.25 g, $n^{19}D$ 1.5235) was oxidized in the same manner as before with chromium trioxide in acetic acid. Here, we obtained 1.44 g of the same p-chlorobenzoic acid with m. p. 242-243° (yield 27% on the two steps).

Investigation of the middle fraction. The middle fraction (b. p. 73.5-74.5° at 2 mm, $n^{20}D$ 1.5180) is apparently a mixture of the dimers, 4-(1-chlorovinyl)-1-chlorocyclohexene (III) and 3-(1-chlorovinyl)-1-chlorocyclohexene (IV).

To 70 ml of concentrated sulfuric acid, with cooling in an ice-salt mixture and vigorous stirring, was added 25 g of this fraction in 1 minute. The stirring was continued for 1 hour and was accompanied by the copious evolution of hydrogen chloride, after which the reaction mass was poured over ice and neutralized with sodium carbonate. After repeated extraction with ether (8 times with 30 ml portions of ether) and drying over magnesium sulfate, the ether was distilled off and the residue was vacuum-distilled. We obtained 15 g (73%) of a mixture of 3- and 4-acetylcyclohexanones with b. p. 109-110° (4 mm). Freezing the mixture, with the addition of a seed, gave 5.85 g of crystalline 3-acetylcyclohexanone (39%) with m. p. 40-41°, which was not depressed when the substance was mixed with an authentic specimen [8], and 10 g of a liquid mixture of ketones. From 1 g of this mixture, dissolved in 2 ml of alcohol, and 1.4 g of hydroxylamine hydrochloride, 2 g of potassium acetate and 6 ml of water we obtained 0.52 g of 4-acetylcyclohexanone dioxime, m. p. 146-147°, which was not depressed when the substance was mixed with the specimen obtained earlier [9] (the yield of the dioxime was 28%, based on the entire starting mixture).

Investigation of the high-boiling fraction. The fraction with b. p. 77.5-85.5° (0.5 mm) and $n^{20}D$ 1.5180 is mainly the eight-membered dimer, 1,6-dichloro-1,5-cyclooctadiene (V). To 16 ml of concentrated sulfuric acid, with vigorous stirring and cooling in ice water, was added 5 g of this fraction in 12 min, after which the reaction product was stirred for another 20 min at room temperature. The reaction mass was poured over ice, neutralized with sodium carbonate, extracted with ether, and the extract dried over magnesium sulfate. The ether was distilled off and the residue was vacuum-distilled. We obtained 2.37 g (69.6%) of the bicyclic ketone, bicyclo[3.3.0]-1(5)-octen-2-one (XII), with b. p. 74-75.5° (1 mm) and $n^{25}D$ 1.5202. The semicarbazone of the compound had m. p. 231-232°.

Literature data [7]: b. p. 65-66° (0.5 mm), $n^{25}D$ 1.5202. Semicarbazone, m. p. 230-232.2°.

SUMMARY

The dimerization of chloroprene was studied at 15-20° and it was shown for the first time that the mixture of products obtained here contains, besides the para isomers, 4-vinyl-1,4-dichlorocyclohexene and 4-(1-chloro-

vinyl)-1-chlorocyclohexene, and the eight-membered dimer, 1,6-dichloro-1,5-cyclooctadiene, also a substantial amount of the meta dimer, 3-(1-chlorovinyl)-1-chlorocyclohexene.

The meta dimer is apparently formed in a somewhat larger amount than the para dimer, 4-(1-chlorovinyl)-1-chlorocyclohexene, which is analogous to the ratio of similar dimers obtained in the low-temperature dimerization of isoprene.

LITERATURE CITED

[1] I. N. Nazarov, A. I. Kuznetsova, and N. V. Kuznetsov, Zhur. Obshchei Khim. 25, 307 (1955).*

[2] I. N. Nazarov, N. V. Kuznetsov, and A. I. Kuznetsova, Zhur. Obshchei Khim. 25, 320 (1955).*

[3] W. H. Carothers, I. Williams, A. M. Collins, and J. E. Kirby, J. Am. Chem. Soc. 53, 4211 (1931).

[4] J. G. Brown, J. D. Rose, and J. L. Simonsen, J. Chem. Soc. (1944), 101.

[5] A. L. Klebanskii and M. M. Denisova, Zhur. Obshchei Khim. 17, 703 (1947).

[6] R. E. Foster and R. S. Schreiber, J. Am. Chem. Soc. 70, 2303 (1948).

[7] A. C. Cope and W. J. Bailey, J. Am. Chem. Soc. 70, 2305 (1948); A. C. Cope and W. R. Schmitz, J. Am. Chem. Soc. 72, 3056 (1950).

[8] A. McCoubrey, J. Chem. Soc. (1951), 2931.

[9] I. N. Nazarov, G. P. Verkholetova, and L. D. Bergel'son, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk (1940), 1948.

* Original Russian pagination. See C. B. translation.

THE DIMERIZATION OF 2-PHENYLBUTADIENE

I. N. Nazarov and A. I. Kuznetsova

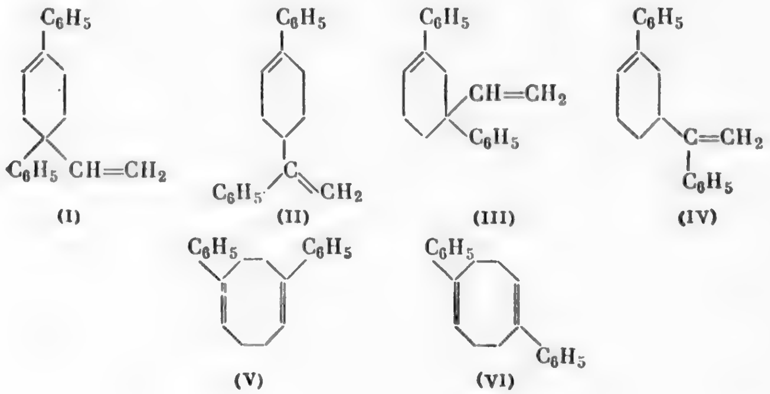
Institute of Organic Chemistry, Academy of Sciences, USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 139-144, January, 1960

Original article submitted January 15, 1959

It is known from [1] that dimerization of 2-phenylbutadiene, both at 160 and at 20°, leads mainly to formation of a six-membered cyclic dimer (I) with substituents in the para-position (about 80%); among the products of reaction performed at 160° was also identified the dimer (II) although these authors were unable to isolate it in the pure state. However, in the dimerization of isoprene [2] and piperylene [3] we established that dimerization is accompanied by formation of all of the theoretically possible six- and eight-membered cyclic dimers; in the case of isoprene the reaction is also strongly temperature-dependent.

It was of interest to establish whether also in the dimerization of 2-phenylbutadiene meta-substituted dimers (III) and (IV) as well as eight-membered dimers (V) and (VI) were obtained and whether the reaction temperature influences their ratio in the mixture.

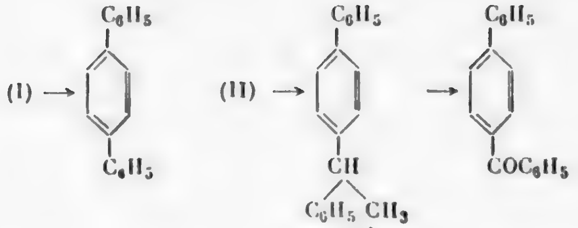


(I) (II) (III) (IV)

(V) (VI)

Our investigations showed that keeping of 2-phenylbutadiene in presence of pyrogallol for a year leads to 75% transformation into a mixture of crystalline (77%) and liquid (20%) dimers. Fractional crystallization of the mixture gave dimer (I) (69%) which had previously been obtained [1]; in addition a small quantity (7.6%) of dimer (II) was isolated for the first time.

Dehydrogenation of dimer (I) in presence of palladium-on-carbon gave terphenyl; the identity of the former with the product described in the literature was also proven [1]. Performance of this reaction as described for dehydrogenation of gem-dimers of isoprene [2] leads to a series of secondary products so that the yield of terphenyl reaches a maximum of only 20%.

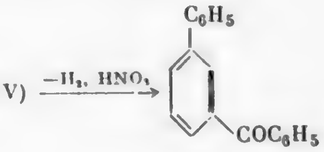


(VII)

Dimer (II) is dehydrogenated with very much greater facility: heating with palladium-on-carbon gives 1-(1'-phenyl)-ethyl-4-phenylbenzene in good yield (80%); it is readily oxidized to p-phenylbenzophenone by nitric acid under pressure. Employment of nitric acid under pressure as an oxidant served in this case, just as in investigation of the products of dimerization of isoprene [2], as a good method of establishing the structure of the dimers formed. Oxidation under these conditions of alkylaryl-substituted aromatic hydrocarbons proved a convenient method of synthesis of the corresponding benzophenones.

As indicated above, the dimerization of 2-phenylbutadiene at 20-30° gave, apart from crystalline products, about 20% of a liquid mixture of dimers which could not be separated into its components. This mixture was combined with the residues from distillation of the alcohol from the mother liquors after recrystallization of dimers (I) and (II); it was then distilled in vacuo and the distillate and residue were examined separately.

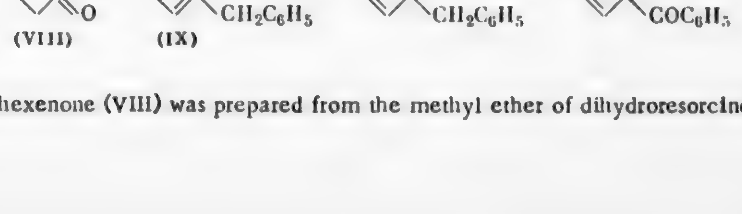
The distillate was dehydrogenated in presence of palladium-on-carbon; chromatography of the dehydrogenation products yielded terphenyl, corresponding to dimer (I), and 1-(1'-phenyl)ethyl-4-phenylbenzene (VII), corresponding to dimer (II). Oxidation of the dehydrogenation products with nitric acid gave p-phenylbenzophenone [confirming the presence of dimer (I)] and a small quantity of m-phenylbenzophenone, so demonstrating the presence in the mixture of dimer (IV) with a meta-structure.



The acidic products resulting from oxidation contained a small quantity of benzoic acid and a mixture of higher boiling acids which were not further examined.

Chromatography of the viscous residue after vacuum distillation of the liquid mixture of dimers yielded a further 10% of dimer (II) and 30% of liquid products which were shown by dehydrogenation and then by oxidation to also contain dimers (I), (II), and (IV). The eight-membered dimers (V) and (VI) and dimer (III) were not detected during a study of the low-temperature dimerization of 2-phenylbutadiene.

The m-phenylbenzophenone needed for identification of dimer (IV) was specially synthesized from 3-phenyl-Δ^2-cyclohexenone (VIII);* reaction of the latter with benzylmagnesium chloride followed by hydrolysis gave 1-phenyl-3-benzyl-$\Delta^{1,3}$-cyclohexadiene (IX). This was dehydrogenated in presence of palladium-on-carbon and the dehydrogenated product oxidized by nitric acid to m-phenylbenzophenone.



(VIII) (IX)

* 3-Phenyl-Δ^2-cyclohexenone (VIII) was prepared from the methyl ether of dihydroresorcinol [4].

Dimerization of 2-phenylbutadiene at 220-230° also leads to a crystalline mixture of dimers (80%) from which dimer (I) (57%) and dimer (II) (12%) were isolated by fractional crystallization. The mother liquors after recrystallization were evaporated and distilled in vacuo. No crystalline products were detected on chromatographic treatment of this mixture or of the residue from distillation of the liquid mixture in vacuo. The liquid reaction products were combined and ozonized, and 1,2-dibenzoylethane (X) was isolated from the neutral part. This indicates the presence in the liquid mixture of 1,4-diphenyl-$\Delta^{4,8}$-cyclooctadiene (V). It was impossible to fractionate the acid products resulting from ozonization.

$$(V) \longrightarrow \underset{(X)}{C_6H_5COCH_2CH_2COC_6H_5} + HOOCCH_2CH_2COOH$$

We see from the foregoing facts that dimerization of 2-phenylbutadiene both at 20° and 220° gives predominantly products with substituents in the para-position. With rising temperature the quantity of gem-dimer (I) falls slightly, but that of dimer (II) increases. At low temperature the reaction products included dimer (IV) with substituents in the meta-position. In spite of a careful search, meta-terphenyl and consequently also the second gem-dimer (IV) were not detected. The eight-membered dimer (V) was found in addition among the liquid products obtained at 220°.

Consequently, the dimerization of a diene with an aromatic substituent (2-phenylbutadiene) is likewise accompanied by formation of most of the theoretically possible dimers (I), (II), (IV), and (V).

EXPERIMENTAL

2-Phenylbutadiene [b. p. 62° (13 mm), $n^{20}D$ 1.5489] was prepared by dehydration of methylphenylvinylcarbinol over potassium bisulfate [5].

Dimerization of 2-phenylbutadiene at 20-30°. In a cork-stoppered dark-glass flask 400 g of 2-phenylbutadiene, 5 g of pyrogallol and 50 ml of ether were kept for a year. The greater part of the diene changed into a mixture of dimers which partly crystallized. The crystalline product was filtered off and recrystallized from methanol to give 107 g of 4-vinyl-1,4-diphenylcyclohexene-1 (I) with m. p. 63.5-64°; colorless needles [1].

Found %: C 92.03; H 7.80. $C_{20}H_{20}$. Calculated %: C 92.25; H 7.75.

From the mother liquor was isolated a further 4.8 g of the same dimer (I) with m. p. 63-64°. Distillation of the alcohol yielded 15 g of an oil which was added to the liquid mixture of dimers. The latter were distilled in vacuo to give 76.4 g of a fraction boiling over the range of 55 to 98° (9 mm) and evidently comprising a mixture of acetophenone, methylphenylvinylcarbinol and 2-phenylbutadiene. The residue (203 g) crystallized. Repeated fractional crystallization of the latter from methanol yielded a further 63.5 g of dimer (I) with m. p. 63.5-64° (no depression in admixture with the sample previously obtained) and 19.2 g of 4-vinyl-(1'-phenyl)-1-phenylcyclohexene-1 (II) with m. p. 57-58°; colorless plates.

Found %: C 92.30; H 7.78. $C_{20}H_{20}$. Calculated %: C 92.25; H 7.75.

In addition, 15.1 g of crystalline dimers was obtained; these could not be fractionated and they were combined with the oil separated after the alcohol had been distilled off from the mother liquors from recrystallization of dimers (I) and (II) and after distillation in vacuo. This procedure yielded 39.4 g of a liquid mixture of dimers with b. p. 204-220° (5 mm), $n^{20}D$ 1.6025 and 25.6 g of a viscous residue. The liquid mixture of dimers and the residue were examined separately.

Dehydrogenation of dimer (I). Three g of dimer (I) with m. p. 63.5-64° and 1.1 g of 30% palladium-on-carbon were heated at 320° in a nitrogen stream for 12 hours. Recrystallization of the reaction product from ethyl acetate gave 0.55 g of terphenyl with m. p. 207° which did not give a depression of melting point in admixture with an authentic specimen. Distillation of solvent from the mother liquor gave 1.5 g of noncrystallizing oil.

Dehydrogenation of dimer (II). Dimer (II) (4 g) with m. p. 57-58° and 30% palladium-on-carbon (1.6 g) were heated at 320-330° for 12 hours. The reaction product was extracted with ether and the ether driven off.

There was obtained 3.2 g of 1-(1'-phenyl)-ethyl-4-phenylbenzene (VII) with m. p. 59-62° (80%); the m. p. was 61-62° (constant) after recrystallization from methanol.

Found %: C 92.99; H 6.93. $C_{20}H_{18}$. Calculated %: C 92.98; H 7.02.

Oxidation of 1-(1'-phenyl)-ethyl-4-phenylbenzene (VII). Treatment of 3.5 g of (VII) (m. p. 61.5-62°) with 54 ml of 5% nitric acid was carried out in an autoclave (250 ml capacity) at a nitrogen pressure of 40 atm at 180-195° for 2.5 hours [2]. The reaction product was extracted with ether, the extract was dried with magnesium sulfate, and the ether driven off. There was obtained 2.9 g (82%) of p-phenylbenzophenone with m. p. 101-102° (from alcohol). A mixture with an authentic specimen did not give a depression of melting point.*

Oxidation of 1,1-diphenylethane. Oxidation of 2 g of 1,1-diphenylethane (b. p. 124-126° at 8 mm, $n^{17}D$ 1.5730) was effected with 53 ml of 4.5% nitric acid under the preceding conditions. The resulting product was extracted with ether, and the ether was distilled off to leave 1.6 g (80%) of benzophenone which gave an oxime with m. p. 139-140° in agreement with the literature.

Investigation of the liquid mixture of dimers with b. p. 204-220° (5 mm), $n^{20}D$ 1.6025. 1) A mixture of dimers (6 g) and 30% palladium-on-carbon (1.6 g) was heated at 320-330° for 12 hours. The reaction product was extracted with ether and the ether was driven off to leave 0.22 g of terphenyl with m. p. 207° and 4.4 g of liquid dehydrogenation products. Chromatographic treatment of the latter on 200 g of alumina (activity not below second degree) and elution with ligroine and with ligroine-benzene mixture gave 0.54 g of 1-(1'-phenyl)-ethyl-4-phenylbenzene (VII) with m. p. 61-62°, and a further 0.02 g of terphenyl with m. p. 207°. Mixtures of terphenyl and (VII) with authentic specimens did not give depressed melting points.

m-Terphenyl was not detected among the products isolated by chromatography.

2) 6.1 g of the same mixture and 1.6 g of palladium-on-carbon (20%) were heated at 310-320° for 12 hours. The usual working-up yielded 0.32 g of terphenyl with m. p. 207° (no melting point depression in admixture with an authentic specimen) and 4.46 g of liquid products. The latter were then heated in an autoclave under a nitrogen pressure of 40 atm with 85 ml of 5% nitric acid at 190-200° for 2 hours. The reaction product was extracted with ether and the ether solution washed with sodium carbonate solution. The solution of the salts was acidified and extracted with ether. The two ethereal solutions were dried with calcium chloride. Distillation of the ether from the acid products gave 0.9 g of residue. Sublimation of this residue yielded benzoic acid with m. p. 121° (no depression of melting point in admixture with benzoic acid) and 0.07 g of acids with m. p. 110-156° which were not further investigated. The neutral products (after distillation of the ether) were chromatographed in a column on 50 g of alumina and eluted with ligroine and benzene. This procedure yielded 0.69 g of p-phenylbenzophenone with m. p. 103° and 0.12 g of m-phenylbenzophenone with m. p. 79-80°. Mixtures of these ketones with authentic specimens did not give depressed melting points. m-Terphenyl was again not detected.

Investigation of the residue after distillation of the liquid mixture of dimers. The dark viscous residues (20.8 g) were chromatographed on alumina (300 ml) and eluted with ligroine to give 2.1 g of dimer (II) with m. p. 57-58° and 6.7 g of liquid mixture of dimers.

4.1 g of this mixture and 1.7 g of palladium-on-carbon (30%) were heated at 330° for 12 hours. Working-up in the usual manner gave 0.12 g of terphenyl with m. p. 207° (no melting point depression in admixture with an authentic specimen) and 2.5 g of liquid residue. The latter was oxidized by heating with 5% nitric acid (43 ml) as described for the preceding experiment.

The usual working-up yielded 2.05 g of neutral products, in the form of a mixture of oil and crystals, and 0.38 g of acid products (the latter were not further examined). The neutral products were chromatographed on alumina (40 ml) and eluted with ligroine and benzene to give 0.2 g of p-phenylbenzophenone, m. p. 103°, and 0.12 g of m-phenylbenzophenone, m. p. 79-80°. Mixtures of the preparations with authentic specimens did not exhibit melting point depressions.

* p-Phenylbenzophenone was specially synthesized from diphenyl and benzoyl chloride in presence of $AlCl_3$ in nitrobenzene solution (yield 80%).

3-Phenyl-Δ^2-cyclohexenone (VIII). A Grignard reagent was prepared from 15.6 g of bromobenzene and 2.4 g of magnesium, and a solution of 10 g of the methyl ether of dihydroresorcinol in 300 ml of ether was added. The reaction product was decomposed with 100 ml of 10 % sulfuric acid, and the main bulk of ether was distilled off on a water bath. The residue was poured into ligroine (b. p. 30-60°) and 7 g of 3-phenyl-Δ^2-cyclohexenone was deposited; m. p. 63-64°.

1-Phenyl-3-benzylcyclohexadiene-1,3 (IX). To the Grignard reagent prepared from 10 ml of benzyl chloride and 1.7 g of magnesium was added a solution of 4 g of 3-phenyl-Δ^2-cyclohexenone in 10 ml of ether with cooling. After working-up in the usual manner and distillation of the ether, the product was distilled in vacuo to give 4.5 g of 1-phenyl-3-benzylcyclohexadiene-1,3 (IX) with b. p. 219-221° (9 mm), m. p. 130° (from alcohol).

Found %: C 92.16; H 7.40. $C_{19}H_{18}$. Calculated %: C 92.52; H 7.48.

m-Phenylbenzophenone. Diene (IX) (4.33 g) was heated with 30% palladium-on-carbon (1 g) at 300° for 4 hours. After the usual working-up and distillation of the ether, the residue consisted of 4.35 g of a viscous fluorescent liquid identified as m-benzyldiphenyl. This was subjected to oxidation without distillation.

A mixture of 3.2 g of this product and 22 ml of 4% nitric acid was heated at 180-200° under a nitrogen pressure of 40 atm for 2 hours. The reaction product was extracted with ether, washed with bicarbonate solution, and dried with magnesium sulfate. The ether was driven off to leave 2.95 g of residue which was chromatographed on alumina and eluted with a mixture of ligroine and benzene. Subsequent recrystallization from isooctane yielded 1.5 g of m-phenylbenzophenone with m. p. 80° (54.5°). The literature [6] reports m. p. 79° (from ligroine).

Dimerization of 2-phenylbutadiene at 220-230°. A round-bottomed flask, fitted with reflux air condenser, dropping funnel and thermometer (the latter extending to the bottom), was first heated to 200°; addition was then made in the course of 10 min of 46.5 g of 2-phenylbutadiene containing 0.2 g of hydroquinone. Within two minutes after the addition the temperature of the mixture had risen to 220°, and it was held at 220-230° for 1.5 hours. The reaction product was distilled in vacuo. There was obtained 2.6 g of a substance with b. p. 85° (7 mm), $n^{24}D$ 1.5345, 37.64 g of a mixture of dimers with b. p. 207-209° (7 mm), $n^{24}D$ 1.6035 (the product crystallized), and 4.2 g of residue. Numerous fractional crystallizations of this mixture of dimers from methanol gave 21.55 g of dimer (I) with m. p. 63-64° and 4.48 g of dimer (II) with m. p. 57-58°. Mixtures of each product with authentic specimens did not exhibit melting point depressions. The mother liquors were evaporated after recrystallization. The residue was distilled in vacuo to give 6.26 g of a substance with b. p. 193-200° (5 mm), $n^{22}D$ 1.6060 and 1 g of residue. No crystalline products were isolated when this fraction (as well as the residue) was chromatographed on alumina; the liquid products were combined and the resulting mixture of dimers was ozonized.

Ozonized oxygen (6% ozone) was passed at 0° through a solution of 1.4 g of this mixture in 50 ml of acetic acid at a rate of 6-7 liters/hour for 2 hours. To the solution was added 3.8 ml of peracetic acid. The liquid was heated at 50-60° for 12 hours and at 100° for 1 hour. The acetic acid was removed in vacuo. The residue was dissolved in ether and washed with sodium carbonate solution. The salts of the acids were evaporated to a volume of 2 ml, acidified with hydrochloric acid and extracted with ether. Both of the ethereal solutions were dried with magnesium sulfate. Removal of the ether from the neutral products left 0.79 g of residue; the latter was chromatographed on alumina (20 ml) and eluted with ether to give 0.05 g of 1,2-dibenzoylethane (IX) with m. p. 145°; the latter did not give a depression of melting point in admixture with an authentic specimen. There was also obtained 0.89 g of acid products in the form of a mixture of crystals and oil from which no pure substances could be isolated.

SUMMARY

The main products of dimerization of 2-phenylbutadiene at 20-30° and 220-230° are dimers with substituents in the para-position: 4-vinyl-1,4-diphenylcyclohexene-1 (obtained previously) and 4-vinyl-(1'-phenyl)-1-phenylcyclohexene-1 (here isolated for the first time).

Among the reaction products were also detected a six-membered dimer, 3-vinyl-(1'-phenyl)-1-phenylcyclohexene-1, with a substituent in the meta-position, and an eight-membered dimer 1,4-diphenyl-$\Delta^{4,8}$-cyclooctadiene.

The ratio of dimers changes slightly at higher temperature.

A new synthesis of m-phenylbenzophenone from the methyl ether of dihydroresorcinol is described.

LITERATURE CITED

[1] K. Alder and J. Haydn, Lieb. Ann. 570, 201 (1950).

[2] I. N. Nazarov, A. I. Kuznetsova, and N. V. Kuznetsov, Zhur. Obshchei Khim. 25, 307 (1955).*

[3] I. N. Nazarov, N. V. Kuznetsov, and A. I. Kuznetsova, Zhur. Obshchei Khim. 25, 320 (1955).*

[4] G. F. Woods and J. W. Tucker, J. Am. Chem. Soc. 70, 2174 (1948).

[5] I. N. Nazarov and V. F. Ryabchenko, Izvestiya Akad. Nauk SSSR, Otdel. Khim. Nauk (1956), 1370.*

[6] H. H. Hatt, A. Pilgrim, and E. F. M. Stephenson, J. Chem. Soc. (1941), 481.

* Original Russian pagination. See C. B. translation.

SOME REACTIONS OF 2-NITROMETHYLQUINOLINE

III. THE REACTION WITH α,β-UNSATURATED KETONES

L. Zalukajevs and E. Vanags

Voronezh Agricultural Institute and Institute of Chemistry,

Academy of Sciences, Latvian SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 145-147, January, 1960

Original article submitted January 5, 1959

Addition of substances containing a nitromethyl group to the double bond of α,β-unsaturated ketones [1] has often been described in the literature. It is expressed by the equation

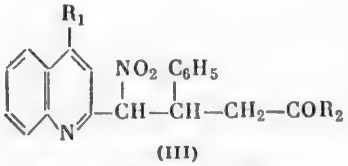
$$>C{=}CHCOR + R_1CH_2NO_2 \longrightarrow \begin{array}{l} >C{-}CH_2COR \\ | \\ R_1{-}CHNO_2. \end{array}$$

and leads to formation of γ-nitroketones.

Phenylnitromethane, for example, in presence of bases adds on with facility to benzylideneacetophenone [2] to form γ-nitro-β,γ-diphenylbutyrophenone (I) in 86% yield, and to vinylphenyl ketone [3] with formation of γ-nitro-γ-phenylbutyrophenone in roughly the same yield.

$$\begin{array}{l} C_6H_5{-}CH{-}CH_2{-}CO{-}C_6H_5 \\ \qquad\quad | \\ C_6H_5{-}CHNO_2 \quad (I) \end{array} \qquad \begin{array}{l} C_6H_5{-}CH{-}CH_2{-}CH_2{-}CO{-}C_6H_5 \\ \qquad\quad | \\ \qquad NO_2 \qquad\qquad (II) \end{array}$$

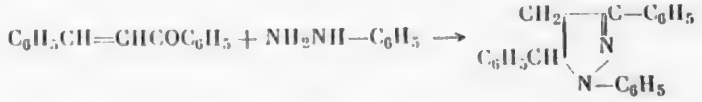
There were good grounds for expecting formation of analogous compounds from 2-nitromethylquinoline since it chemically resembles arylnitromethanes, although surpassing the latter in respect of methylenic group activity. This expectation was fully justified. Heating of 2-nitromethylquinoline with chalcone and of 2-nitromethyl-4-methylquinoline [4] with chalcone and benzylideneacetone gave derivatives of the general formula (III).



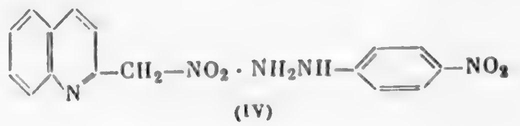
(III)

$R_1 = H,\ CH_3$; $R_2 = CH_3,\ C_6H_5$.

The reaction proved to be reversible. When heated with bases (phenylhydrazine, p-nitrophenylhydrazine, aniline), γ-nitrobutyrophenones again suffer loss of the elements of 2-nitromethylquinoline, due to which chalcone and the quinoline derivative react with the amines independently of one another. Reaction of phenylhydrazine with γ-nitro-γ-(quinolyl-2)-β-phenylbutyrophenone thus gives 1,3,5-triphenylpyrazoline.



This reaction has already been described in [5]. p-Nitrophenylhydrazine reacts with formation of addition compound (IV) which can also be obtained by heating 2-nitromethylquinoline with p-nitrophenylhydrazine.



(IV)

γ-Nitro-γ-(4-methylquinolyl-2)-β-phenylbutyrophenone behaves in exactly the same manner.

EXPERIMENTAL

1. γ-Nitro-γ-(quinolyl-2)-β-phenylbutyrophenone (III, $R_1 = H$; $R_2 = C_6H_5$). Chalcone (3 g), 2-nitromethylquinoline (3 g), alcohol (40 ml) and nine drops of triethylamine were heated on a water bath for 5-6 hours; the solution was then stood overnight at room temperature. The resulting crystals were filtered. M. p. 163°. Weight 5.2 g (90%). Recrystallization from glacial acetic acid did not alter the melting point. The yield is lowered if alcoholic sodium methoxide and ethoxide are used.

Found %: C 75.84; H 5.22; N 7.11. $C_{25}H_{20}O_3N_2$. Calculated %: C 75.75; H 5.05; N 7.07.

2. Cleavage of γ-nitro-γ-(quinolyl-2)-β-phenylbutyrophenone by bases. a) Phenylhydrazine. γ-Nitro-γ-(quinolyl-2)-β-phenylbutyrophenone (1 g), phenylhydrazine (1.2 g) and glacial acetic acid (10 ml) were boiled for 15 min. On standing, yellow needles came down with m. p. 136°. Weight 0.4 g.

Found %: N 9.43. $C_{21}H_{18}N_2$. Calculated %: N 9.39.

A mixture with authentic 1,3,5-triphenylpyrazoline, prepared by heating chalcone with phenylhydrazine, melted without depression [5].

b) p-Nitrophenylhydrazine. Glacial acetic acid (15 ml) was added to 1 g γ-nitro-γ-(quinolyl-2)-β-phenylbutyrophenone and 2 g of p-nitrophenylhydrazine, and the mixture boiled for 15 min. Brownish, elongated plates came down on cooling; m. p. 208° (from glacial acetic acid and from alcohol).

Found %: N 20.86. $C_{16}H_{15}O_4N_5$. Calculated %: N 20.52.

The same product (IV) was obtained from p-nitrophenylhydrazine and 2-nitromethylquinoline in glacial acetic acid. M. p. 208°. A mixture of the two substances melted without depression.

3. γ-Nitro-γ-(4-methylquinolyl-2)-β-phenylbutyrophenone (III, $R_1 = CH_3$; $R_2 = C_6H_5$). A mixture of 6 g of 2-nitromethyl-4-methylquinoline and 6 g of chalcone was heated in 80 ml of alcohol in presence of ten drops of triethylamine on a water bath for 5 hours. The precipitate was recrystallized from alcohol. Light-yellow needles with m. p. 151-152°. Yield 8.7 g (71%).

Found %: C 75.90; H 5.47; N 7.07. $C_{26}H_{22}O_3N_2$. Calculated %: C 76.10; H 5.36; N 6.83.

4. Cleavage of γ-nitro-γ-(4-methylquinolyl-2)-β-phenylbutyrophenone by bases. a) Phenylhydrazine. The reaction was performed as in 2a. 1,3,5-Triphenylpyrazoline was obtained with m. p. 136°.

b) Aniline. γ-Nitro-γ-(4-methylquinolyl-2)-β-phenylbutyrophenone (1 g) was boiled with aniline for 45 min. The mixture was dissolved in glacial acetic acid. The resulting precipitate was recrystallized from glacial acetic acid. M. p. 167-168°; no depression in admixture with authentic chalcone anil.

Found %: N 4.83. $C_{21}H_{17}N$. Calculated %: N 4.95.

5. γ-Nitro-γ-(4-methylquinolyl-2)-β-phenylpentanone-2 (III, $R_1 = CH_3$; $R_2 = CH_3$). A mixture of 4.4 g of 2-nitromethyl-4-methylquinoline, 3.6 g of benzylideneacetone, 15 drops of triethylamine and 60 ml of alcohol was heated on a water bath for 4 hours. The brownish solution deposited 3.7 g of substance on cooling. Evaporation of the mother liquor gave a further 1.7 g of the substance. The precipitates were combined and 2.9 g of lustrous yellow plates was obtained after two recrystallizations from alcohol. M. p. 150-151°.

Found %: C 72.71; H 6.45; N 8.07. $C_{21}H_{20}O_3N_2$. Calculated %: C 72.91; H 6.72; N 8.05.

6. γ-Nitro-γ-(p-nitrophenyl)-β-phenylbutyrophenone. A mixture of 0.9 g of p-nitrophenylnitromethane, 1 g of chalcone, 15 ml of alcohol and five drops of triethylamine was heated on a water bath for 2.5 hours. The product first came down in the form of an oil which later crystallized. Colorless needles with m. p. 178° after recrystallization from alcohol. Yield 0.85 g. Further recrystallization did not alter the melting point.

Found %: C 67.70; H 4.81; N 7.10. $C_{22}H_{18}O_5N_2$. Calculated %: C 67.69; H 4.61; N 7.18.

SUMMARY

A study was made of the addition of 2-nitromethylquinoline and its 4-methyl derivative to an electrophilic double bond, and the corresponding derivatives of butyrophenone were obtained.

LITERATURE CITED

[1] L. Zalukaev and É. Vanag, Zhur. Obshchei Khim. 28, 483 (1958).*

[2] E. Kohler, J. Am. Chem. Soc. 41, 1738 (1924).

[3] C. Allen and M. Bridges, J. Am. Chem. Soc. 51, 2153 (1929).

[4] L. Zalukaev and É. Vanag, Zhur. Obshchei Khim. 29, 1639 (1959).*

[5] L. Knorr and H. Laubmann, Ber. 21, 1210 (1888).

* Original Russian pagination. See C. B. translation.

FURAN COMPOUNDS

X. THE BROMINATION OF 1,6-DIOXASPIRO(4,4)NONANE AND ITS HOMOLOGS BY COMPLEXLY BOUND BROMINE

A. A. Ponomarev and A. D. Peshekhonova

Saratov N. G. Chernyshevskii State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 147-151, January, 1960

Original article submitted January 22, 1959

Spirans of the 1,6-dioxaspiro(4, 4)nonane group became known through the work of Fittig [1, 2] and Volhard [3] who obtained several representatives of these compounds from butyro-, valero- and caprolactones and from diallylacetone, and also established their structure.

The simplest spiran of this series – 1,6-dioxaspiro(4,4)nonane – was also isolated from the products of hydrogenation of furylacrolein under pressure in presence of Raney nickel, and some of its homologs were prepared by hydrogenation of furfurylideneacetone, difurfurylideneacetone, furfurylidenebutanol or the corresponding furanic alcohols [4-7].

A large group of 2-alkyl- and phenyl-substituted spirans was later synthesized by one of us and co-workers by hydrogenation of a series of secondary furylalkanols [8]. It was subsequently shown [9] that tertiary γ-furylalkanols are similarly hydrogenated over nickel catalysts to give 2,2-dialkyl-1,6-dioxaspiro(4, 4)nonanes.

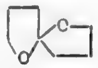
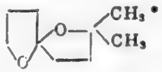
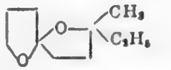
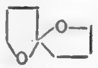
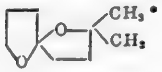
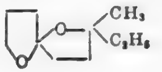
The mechanism of formation of spirans from γ-furylalkanols was experimentally clarified by one of us [10].

Chemically 1,6-dioxaspiro(4,4)nonane and its homologs are internal cyclic acetals with properties typical of this class of compounds. For example, HBr and HI cleave them to form derivatives of γ,γ'-diiodo- or dibromoketones [1, 3, 6]. It was also shown that, like all acetals, these spirans react with organomagnesium compounds to form compounds of the tetrahydrofuran series [11]. At the same time, 1,6-dioxaspiro(4, 4) nonane and its homologs are chemically very much more stable than the simple acetals.

The behavior of compounds of this group with halogenating agents is interesting. It has long been known [1, 12] that 1,6-dioxaspiro(4,4)nonane and some of its homologs interact with bromine with liberation of hydrogen bromide. This behavior is indicative of a substitution reaction. The same authors were unable, however, to isolate any pure substances. Only recently [5] was 1,6-dioxaspiro(4,4)nonane brominated with bromine in dry ether and with isolation of a small quantity (yield not stated) of a white crystalline substance, m. p. 113°, formula $C_7H_{10}O_2Br_2$; structure not clarified.

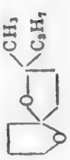
We repeated this experiment and found that under these conditions a crystalline substance is indeed formed with formula $C_7H_{10}O_2Br_2$, m. p. 112.5°, yield not exceeding 25%. Attempted bromination under similar conditions of 2-methyl-1,6-dioxaspiro(4,4)nonane led to resinification. We also attempted to replace ethyl ether by an oxygen-free solvent. We found that a crystalline dibromide is formed in 5.5% yield when bromine acts on 1,6-dioxaspiro(4,4)nonane in dry dichloroethane, and that no dibromide is obtained in dry chloroform. Ethyl ether thus proved to be the best medium for bromination of a spiran. This behavior is undoubtedly associated with the well-known ability of ethyl ether to form a molecular compound with bromine.

Mono and Dibromo Derivatives of 1,6-Dioxaspiro (4,4) nonane and Its Homologs

Starting spiran	Formula of bromo derivative	B. p. (pressure in mm)	M. p.	M found	M calc.	n_D^{20}	d_4^{20}	MR_D found	MR_D calc.	% Br found	% Br calc.	Yield (%)
	$C_7H_{11}O_2Br$	70—72° (5)	—	211	207	1.5009	1.497	40.76	41.17	38.39, 38.11	38.59	70
	$C_8H_{13}O_2Br$	80—82 (5)	—	233	221	1.4906	1.406	45.50	45.79	36.22	36.15	55.7 and 26 dibromide
 *	$C_9H_{15}O_2Br$	68—69 (4.5)	—	244	235	1.4830	1.344	49.96	50.41	33.62, 33.15	34.04	58
	$C_{10}H_{17}O_2Br$	87—89 (5)	—	259	249	1.4840	1.304	54.66	55.03	32.08, 32.22	32.07	76
	$C_7H_{10}O_2Br_2$	105—108 (5)		289	286	1.5408	1.856	48.39	48.94	55.84, 55.85	55.88	45
			112.5°	—	—	—	—	—	—			
	$C_8H_{12}O_2Br_2$	115—118 (5)		308	300	1.5262	1.733	53.14	53.56	52.80, 53.13	53.27	36
			101.5	—	—	—	—	—	—			14
 *	$C_9H_{14}O_2Br_2$	110—112 (5)	—	329	314	1.5163	1.636	51.97	52.18	50.21, 50.12	50.90	64
	$C_{10}H_{16}O_2Br_2$	115—117 (2)	—	325	328	1.5135	1.583	62.35	62.79	48.58	48.72	69

* With participation of M. V. Polyakova.

Table (Continued)

Starting spiran	Formula of bromo derivative	B. p. (pressure in mm)	M.p.	M found	M calc.	n^{20}_D	d^{20}_4	MR_D found	MR_D calc.	% Br found	% Br calc.	Yield (%)
	$C_{11}H_{18}O_2Br_2$	134—136 (5) 123—126 (2)	—	324	342	1.5089	1.525	66.97	66.41	46.0, 46.61	46.72	66
	$C_{12}H_{20}O_2Br_2$	145—147 (4)	—	350	356	1.5062	1.477	71.64	72.03	44.97, 44.98	44.88	73
	$C_{13}H_{22}O_2Br_2$	152—154 (4) 147—148 (3)	—	376	370	1.5048	1.438	76.32	76.65	43.35, 43.55	43.18	68

In the light of the above facts we considered that bromination with bromine in complex form might be successful in the case of 1,6-dioxaspiro(4,4)nonane and its homologs. We chose dioxane dibromide as brominating agent; this had been successfully applied by A. P. Terent'ev and L. A. Yanovskaya [13] for bromination of many substances. The corresponding dibromo derivatives were obtained in satisfactory yield when the spiran/ /dioxane dibromide ratio (molar) was 1 : 2.

We obtained dibromo derivatives of the simplest spiran and of its 2-methyl homolog in two forms — crystalline and liquid. The liquid product could be gradually converted to the solid, for instance after redistillation in vacuo. This may be a case of cis- and trans-isomerism. Bromination of spirans under the same conditions, but using a 1 :1 molar ratio of reactants, gave a monobromospiran as the main product. Highly regular change of physical properties is to be observed within the homologous series of mono- and dibrominated spirans that we prepared (see table). It can be observed, in particular, that the depression of molar refraction characteristic of these substances is of the order of 0.5 ml. That the bromine in the brominated spirans is not combined in complex form is proven — apart from the evidence of hydrogen bromide liberation noted above — by the fact that the corresponding amine salts are formed when the bromospirans are heated with excess of diethylamine and piperidine; similarly sodium bromide is formed on heating with sodium ethoxide. We were unable, however, in these experiments to isolate any pure products — products of replacement of bromine in the spiran by the corresponding groups.

The problem of the structure of bromo derivatives of 1,6-dioxaspiro(4,4)nonane and its homologs is still unsolved; i.e., the position of the bromine in the spiran molecule is unknown (there are many possibilities). The mechanism of bromination of spirans is also obscure. We are continuing our work on all of these aspects.

EXPERIMENTAL

The following examples are typical of the procedure for spiran bromination.

Synthesis of dibrominated 1,6-dioxaspiro(4,4)-nonane. To a cooled solution of 10 g of 1,6-dioxaspiro-(4,4)nonane in 10 ml of dry ether was gradually added, with shaking, 160 ml of ethereal solution containing 39 g of dioxane dibromide; each fresh portion was added after decolorization of the previous one. Toward the end of the experiment the reaction was carried out at room temperature. Two layers formed; the upper (ethereal) layer was collected and washed with 5%

sodium carbonate solution and then with water; the lower layer was neutralized with 10% sodium carbonate solution and the substance present was extracted with ether; the extract was added to the main product which was then dried with calcined magnesium sulfate. The ether was driven off and the residue distilled in vacuo. At 105-108° (5 mm), 10 g of dibromo derivative came over as a heavy liquid which partly crystallized. The crystals were collected; m. p. 112.5° (from alcohol). Analysis of the filtrate indicated that it was also a dibromo derivative; on redistillation it changed to the crystalline form.

Synthesis of monobrominated 1,6-dioxaspiro(4,4)nonane was effected under the same conditions but with use of 1 :1 molar ratio of reactants, i.e., 27 g of dioxane dibromide in 80 ml of ether was added to 13.5 g of spiran in 25 ml of dry ether. The reaction mixture was worked up as above and the bromo derivative isolated in the manner described. Distillation at 70-72° (5 mm) gave 15 g of the monobromo derivative of 1,6-dioxaspiro(4,4) nonane.

Details of some properties and analyses of mono- and dibromo derivatives of various spirans are presented in the table.

SUMMARY

Dioxane dibromide acts on 1,6-dioxaspiro(4,4)nonane and its homologs to form mono- or dibromo derivatives of the spirans (depending on the conditions). A series of previously unknown bromo-substituted spirans was obtained and their properties described.

LITERATURE CITED

[1] R. Fittig, Lieb. Ann. 256, 50 (1890).

[2] R. Fittig, Lieb. Ann. 267, 186 (1892).

[3] Volhard, Lieb. Ann. 267, 48 (1892).

[4] H. Burdick and H. Adkins, J. Am. Chem. Soc. 56, 438 (1934).

[5] A. Hinz, G. Meyer, and G. Schucking, Ber. 76B, 676 (1943).

[6] K. Alexander, L. Hafner, and L. Schniepp, J. Am. Chem. Soc. 73, 2725 (1951).

[7] K. Alexander, L. Hafner, et al., J. Am. Chem. Soc. 72, 5506 (1950).

[8] A. A. Ponomarev, Z. V. Til', I. A. Markushina, and K. Sapunar, Doklady Akad. Nauk SSSR 93, 297 (1953); Zhur. Obshchei Khim. 27, 110 (1957).*

[9] A. A. Ponomarev, Z. V. Til', A. D. Peshekhonova, and V. P. Reshetov, Zhur. Obshchei Khim. 27, 1369 (1957).*

[10] A. A. Ponomarev, V. A. Afanas'ev, and N. I. Kurochkin, Doklady Akad. Nauk SSSR 87, 983 (1952); Zhur. Obshchei Khim. 23, 1426 (1953).*

[11] A. A. Ponomarev, Doklady Akad. Nauk SSSR 92, 975 (1953).

[12] E. Granichstedten and F. Werner, Monatsh. 22, 315 (1901).

[13] A. P. Terent'ev and L. A. Yanovskaya, Zhur. Obshchei Khim. 22, 1594 (1952);*24, 1265 (1954).*

* Original Russian pagination. See C. B. translation.

ALKALINE SAPONIFICATION OF ESTERS AND NITRILS OF ETHYLENEIMINOCARBOXYLIC ACIDS

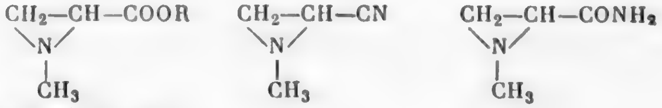
V. K. Antonov and A. Ya. Berlin

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 151-153, January, 1960

Original article submitted December 17, 1958

Ethyleneiminocarboxylic acid derivatives are a relatively new and little studied class of compounds. Their esters were synthesized for the first time in 1953 [1]. We recently described the nitriles [2].

In the present work we studied the behavior of these compounds during alkaline saponification with the objective of isolating the previously unknown free ethyleneiminocarboxylic acids. The sole product of saponification of the methyl ester of N-methylethyleneiminocarboxylic acid (I) with alcoholic NaOH



(I) $R=CH_3$, (II) $R=Na$ (III) (IV)

was the sodium salt of N-methylethyleneiminocarboxylic acid (II). Formation of products of rupture of the three-membered ring were not observed. Attempts to isolate free N-methylethyleneiminocarboxylic acid by exact acidification of its sodium salt were unsuccessful. Acidification resulted in separation of a polymeric substance in accord with the well-known susceptibility of ethyleneimines to polymerization under the influence of the H^+ ion (see, for example, [3]).

Saponification of the nitrile of N-methylethyleneiminocarboxylic acid (III) by boiling with aqueous alcoholic alkali gave the amide of N-methylethyleneiminocarboxylic acid (IV) in about 25% yield together with 40-45% of the sodium salt (II). The structure of the amide was verified by reverse synthesis from ester (I) and alcoholic ammonia.

The quantity of ammonia evolved during saponification of nitrile (III) was determined. It was shown that release of NH_3 ceased substantially after saponification for 1.5 hours, by which time only about 50% of the theoretical amount of ammonia had been collected. This corresponds to the yield of sodium salt of ethyleneiminocarboxylic acid (II). The remaining quantity of original nitrile (after allowing for 25% converted to amide) evidently remains unchanged. This was confirmed by isolation of the hydrobromide of α-bromo-β-methylaminopropionitrile [2] by treatment of the mother liquor with dry hydrogen bromide. Prolongation of the period of saponification of nitrile (III) to 3 hours led to substantially no change in yields and ratio of reaction products.

Saponification of nitrile (III) by 3% H_2O_2 solution and KOH [4] gave amide (IV) in a yield only slightly exceeding 25%.

EXPERIMENTAL

1. Methyl ester of N-methylethyleneiminocarboxylic acid (I). To a solution of 12.3 g of methyl α,β-dibromopropionate in 10 ml of anhydrous benzene was added at 15-20° a mixture of 13.8 ml of triethylamine

with 24 ml of 7.76% solution of methylamine (1.86 g) in benzene. The mixture was heated in an autoclave at 80° for 3 hours, then cooled and filtered. The precipitate of triethylamine hydrobromide was thoroughly washed with benzene, the filtrate was evaporated in vacuo, and the residue distilled. Yield 2.8 g (49%).

B. p. 52-53° (10 mm), $n^{20}D$ 1.4374, d^{20}_4 1.04376, MR_D 28.92; Calc. 28.68.

Found %: C 51.99; H 7.76; N 12.14. $C_5H_9O_2N$. Calculated %: C 52.16; H 7.87; N 12.16.*

2. Sodium salt of N-methylethyleneiminocarboxylic acid (II). Ester (I) (2.3 g) was mixed with a solution of 0.8 g of NaOH in 14 ml of anhydrous methanol. The mixture was boiled for 1 hour and the alcohol driven off. The precipitate was triturated with acetone, filtered, and dried in a desiccator. Yield 1.2 g, m. p. 208-211° (decomp.). The substance was purified by recrystallization from a small quantity of n-butyl alcohol. After five days' standing in a refrigerator, needles were obtained with m. p. 222-223° (decomp.), yield 0.6 g (25 %).

Found %: N 11.59. $C_4H_6O_2NNa$. Calculated %: N 11.38.

To a solution of 0.25 g of (II) in 5 ml of anhydrous alcohol was added 7.5 ml of 1.25% HCl solution in anhydrous alcohol. The precipitated NaCl was filtered off and the filtrate evaporated in vacuo to give 0.32 g of a white polymeric substance, soluble in water and containing the chloride ion.

3. N-Methylethyleneiminocarboxylic acid amide (IV). a) A solution of 0.95 g of ester (I) was prepared in 10 ml of anhydrous alcohol and the solution was saturated with dry ammonia. The mixture was stood at 20° for 3 days, after which the alcohol was distilled off in vacuo, and the residue was treated with hot benzene and filtered. The filtrate was concentrated to $^1/_5$ of its original volume and hexane was added. The resulting precipitate (0.35 g) was recrystallized from a mixture of benzene and hexane. M. p. 100-101°, yield 0.2 g.

Found %: C 48.07; H 8.12; N 27.64. $C_4H_8ON_2$. Calculated %: C 47.98; H 8.06; N 27.98.

b) A mixture of 5.88 g of nitrile (III) [2], 2.9 g of NaOH, 5 ml of water and 20 ml of alcohol was refluxed in a flask for 1.5 hours, the condenser being joined by a gas-leading tube to a flask containing 30 ml of 0.1 N HCl solution. With progressive evolution of NH_3, the HCl in the flask was used up; the HCl was replenished by addition at intervals of fresh batches of 30 ml of HCl solution. In all,360 ml (50%) of HCl was consumed. When saponification was complete, the solvents were distilled off in vacuo, and 15 ml of a 2:1 mixture of benzene and alcohol was added to the residue. An azeotropic mixture of water, benzene and alcohol was distilled off. The operation of addition of 15 ml of benzene/alcohol mixture and distillation of the azeotrope was performed three times in all. The residue was stirred with chloroform and filtered. The product (3.6 g, 42%) was crystallized from n-butyl alcohol to give needles with m. p. 222-223° (decomp.) which did not exhibit a depression in a mixed melting point test with the sodium salt (II) obtained in prep. 2.

The chloroform solution was evaporated to $^1/_5$ of its original volume and treated with hexane. Amide (IV) separated; yield 1.8 g (24.8%), m. p. 98-100°. No depression of melting point in admixture with the amide obtained in prep. 3a.

The filtrate from the separated amide (IV) was treated with a stream of dry HBr. The resulting precipitate (1.1 g) was crystallized from a mixture of alcohol and hexane (1:1) to give a substance with m. p. 133-134°, not giving a melting point depression in admixture with the hydrobromide of α-bromo-β-methylaminopropionitrile [2].

c) A solution of 0.7 g of KOH in 5 ml of water was mixed with 25 ml of 3% H_2O_2. To the mixture was added 1 g of nitrile (III) and the mass was kept for an hour at 20°. The solution was then filtered and evaporated in vacuo. Residual water was removed in a vacuum-desiccator over P_2O_5. The solid residue was boiled with benzene and filtered; the filtrate was treated with hexane. Yield of amide 0.35 g (27.5%), m. p. 99-100°.

SUMMARY

1. The methyl ester and the amide of N-methylethyleneiminocarboxylic acid were synthesized.

* Analyses were made in the analytical laboratory of the Institute.

2. The saponification of the methyl ester and the nitrile of N-methylethyleneiminocarboxylic acid was studied. It was shown that alkaline saponification of the ester gives the sodium salt of N-methylethyleneiminocarboxylic acid, while saponification of the nitrile gives the sodium salt and the amide of the same acid.

3. Acidification of the sodium salt of N-methylethyleneiminocarboxylic acid gives a water-soluble polymer.

LITERATURE CITED

[1] M. A. Stolberg, J. O'Neill, and T. Wagner-Jauregg, J. Am. Chem. Soc. 75, 5045 (1953).

[2] V. K. Antonov, Zhur. Obshchei Khim. 29, 1132 (1959).*

[3] G. Jones, J. Org. Chem. 9, 125 (1944).

[4] Radziszewski, Ber. 18, 355 (1885).

* Original Russian pagination. See C. B. translation.

INVESTIGATION OF BROMINATION WITH DIOXANE DIBROMIDE

I. KINETICS AND MECHANISM OF BROMINATION WITH DIOXANE DIBROMIDE

V. S. Karpinskii and V. D. Lyashenko

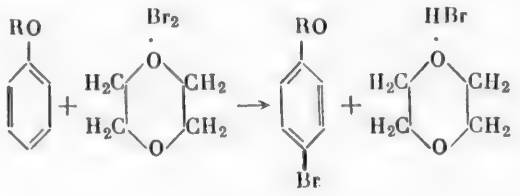
Leningrad Chemicopharmaceutical Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 154-159, January, 1960

Original article submitted December 30, 1958

The complex compound of bromine with dioxane – dioxane dibromide (DDB) – was first prepared and described by A. E. Favorskii [1] but was not used until 1950 [2] for bromination of aromatic hydrocarbons, phenols, aromatic amines, heterocyclic compounds and aliphatic aldehydes and ketones. In contrast, however, to the properties of other brominating agents [2], the brominating properties of DDB have not been the subject of close investigation.

With the objective of qualitative characterization of bromination with DDB, we have studied the kinetics of bromination of three phenolic ethers in benzene. The latter substance is not brominated by DDB [2] either at room temperature or on heating, so that it can be used as a medium for kinetic investigation of the bromination process. The stoichiometric equation of the investigated reaction has the form



Graphical analysis of the experimental data shows that the reaction is third order for equimolar concentrations of reactants (0.015 M) (Fig. 1).

The velocity constants calculated from the formula for trimolecular reactions are distinguished by good constancy; constancy of k_2 is not observed if the velocity constants are calculated from the formula for bimolecular reactions. According to [5] brominating agents can be arranged in the following sequence of activity in an aqueous medium: $BrOH < Br_2 < BrCl < Br^+$.

Ingold [6] considers that the specific activity of brominating agents falls in the following sequence during bromination in hydroxyl-containing solvents:

$$Br^+ > BrOH_2^+ > Br{-}Br > BrOCOCH_3 > BrOH.$$

According to the current electronic theory the activity of a halogenating agent of the Br – X type in processes of electrophilic substitution is determined by the degree of polarization of the Br – X bond. We know that the bromine atom bond in the DDB molecule is more polarized than in the bromine molecule: in crystalline

DDB the distance between the bromine atoms is 2.31 A; in the bromine molecule it is 2.28 A [3]. Hence, the brominating activity of DDB would be expected to surpass that of molecular bromine.

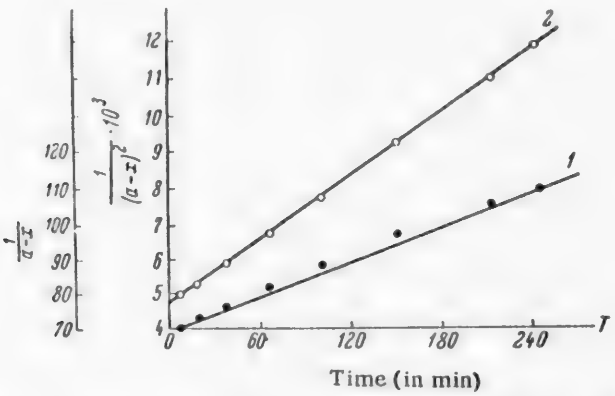


Fig. 1. The function $\frac{1}{a-x}$ versus T. 1) $\frac{1}{a-x}$; 2) $\frac{1}{(a-x)^2}$. a) initial concentration (in M); x) concentration at end of time T (in M).

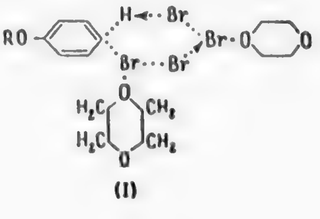
This inference is fully borne out by experimental results. In these experiments an excess of dioxane did not influence the velocity of bromination (Table 1). The rate of bromination of phenetole with excess of DDB is directly proportional to the square of its concentration, while the rate of bromination of excess of phenetole is directly proportional to the first power of the phenetole concentration (Tables 2 and 3).

TABLE 1

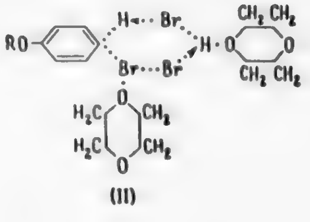
Influence of Dioxane on the Rate of Bromination of Isopropyl Phenyl Ether (Concentration of Isopropyl Phenyl Ether and Brominating Agent 0.015 M. Temperature 25°)

Brominating agent	Bromine	DDB	DDB	DDB	DDB
Dioxane concentration (in M)	–	–	0.1	0.5	2.5
k_3 (liter^2·mole^{-2}·min^{-1})	44.0	57.0	52.4	56.0	52.0

Bromination of phenol ethers by DDB is a process of electrophilic substitution of hydrogen in the benzene ring by bromine. Its trimolecular mechanism is evidently due to the poor donor activity of the π-carbon of the nucleus. This activity is enhanced by the protonizing influence of another molecule of DDB and the process then proceeds via the intermediate complex (I). The rate of the process in presence of dioxane hydrobromide is in complete harmony with this mechanism; a large excess of the lower reduces the reaction to second order due to formation of intermediate complex (II).



(I)



(II)

TABLE 2

Bromination of Phenetole with Excess of DDB

a	$\tau_{0.2}$	k_3
0.010	162	14.9
0.015	78	14.9
0.020	41	15.0
0.025	27	14.6
0.030	18	14.8

Note. a) DDB concentration (in M); phenetole concentration 0.01 M; $T_{0.2}$ is the period during which 20% of the phenetole reacted; DDB consumption is 20% of that theoretically needed for preparation of monobromophenetole.

TABLE 3

Bromination of Excess of Phenetole with DDB

b	$\tau_{0.25}$	k_3
0.010	232	14.9
0.015	152	14.7
0.020	117	15.2
0.030	78	15.0

Note. DDB concentration 0.01 M; b) phenetole concentration (in M); DDB consumption is 25% of the starting concentration; $T_{0.25}$ is the period during which 25% of the DDB reacted (in min).

TABLE 4

Bromination of Phenetole with Dioxane Hydrobromide

Molar concentration of dioxane hydrobromide at start of reaction	—	0.0176	0.088	0.176
Molar concentration of DDB	0.015	0.015	0.015	0.015
Molar concentration of phenetole	0.015	0.015	0.015	0.015
k_2 (liter · mole^{-1} · min^{-1})	11.2 *	42.4	90.0	137.6

* The velocity constant rises if second order is assumed in the calculation; hence the mean value of k_2 is taken for comparison.

Consequently, the reaction in question is third order, and it is expressed by the kinetic equation

$$\frac{dx}{dT} = k_3 (a - x)^2 (b - x)$$

where $\underline{a}$ is the initial concentration of DDB (in moles), $\underline{b}$ is the initial concentration of phenolic ether (in moles), T is the duration from start of experiment, $\underline{x}$ is the consumption of each reactant up to time T (in moles), k_3 is the velocity constant of the reaction (liter^2 · mole^{-2} · min^{-1}).

In presence of dioxane hydrobromide the velocity constant increases, but the previously third order reaction becomes one of second order (see Table 4 and Fig. 2).

EXPERIMENTAL

The following reagents were used: benzene pure for analysis and chemically pure were treated with bromine for removal of impurities capable of absorbing bromine. After removal of the bromine with sodium bisulfate, the benzene was washed with water, dried with alkali and distilled twice over metallic sodium through a 0.5 meter column (b. p. 80°); dioxane, pure grade free of peroxides, was dried with solid sodium hydroxide and metallic sodium and distilled over metallic sodium (b. p. 101°); bromine, chemically pure grade free of iodine, was further purified by the literature method [4]; dioxane dibromide was prepared by mixing dioxane with bromine and filtering the resulting crystals from excess of dioxane on a glass funnel fitted with a glass filter disc (m. p.

64-65°); phenolic ethers were prepared from sodium phenate and the appropriate alkyl halide. The reaction medium was the alcohol corresponding to the alkyl halide used. The resulting ethers were purified, dried and distilled first at normal pressure and then in vacuo; they were then stored in sealed ampoules. Boiling points: anisole 154-155°, phenetole 170-171°, isopropyl phenyl ether 176-177°.

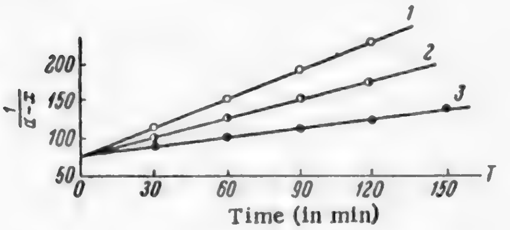


Fig. 2. Function $\frac{1}{a - x}$ plotted against time T for various starting concentrations of dioxane hydrobromide. Starting molar concentrations of dioxane hydrobromide: 1) 0.176; 2) 0.088; 3) 0.0176.

Method of measurement and experimental procedure. Reaction rates were determined from the bromine consumption as estimated by iodometric titration. Experiments were run in the dark to exclude reactions of a radical character; thermostating was accurate to within 0.1°. Solutions of the ethers were prepared by dissolving weighed samples (weighing accurate to 0.001 g) in a measuring flask. In all cases, the solvent was benzene purified as above. Solutions of DDB and bromine were prepared by dissolving a roughly weighed quantity in benzene and then diluting the benzene to the required concentration; the exact concentration was determined by titration by the above method. Reactants were mixed at the temperature of the experiment. Brominating solution was added last in the absence of direct illumination. The resulting mixture was thoroughly stirred and a sample was withdrawn with a 10 ml pipet for determination of the active bromine.

The start of an experiment was taken as the instant of addition of the brominating agent. The error in timing was 0.1 min. The titration error did not exceed 0.1 ml.

The solution of bromine and DDB in benzene was stable for several days under the experimental conditions.

The results of the experiments are set forth in Tables 5-8.

TABLE 5

Influence of Dioxane on the Process of Bromination of Isopropyl Phenyl Ether

Bromine 0.015 D 0.000		DDB 0.015 D 0.000		DDB 0.015 D 0.1		DDB 0.015 D 0.5		DDB 0.015 D 2.5	
T	A	T	A	T	A	T	A	T	A
0.0	27.1	2.6	26.2	1.7	27.25	2.1	29.25	2.0	30.5
4.7	25.8	7.0	27.1	6.7	25.4	8.0	27.7	7.2	28.95
19.3	22.55	17.0	25.0	16.3	23.5	15.6	25.4	17.0	26.75
28.6	22.0	31.8	22.3	30.0	21.05	35.6	22.05	29.3	24.2
34.1	21.65	46.6	20.4	42.8	19.7	52.7	19.9	49.0	21.0
50.0	19.75	61.8	18.7	57.6	18.55	67.1	18.4	61.2	19.8
60.8	18.75	93.4	16.3	74.5	17.35	79.8	17.35	77.3	18.5
94.0	16.95	121.5	14.8	89.9	16.35	90.2	16.7	97.3	17.2
118.5	15.7	—	—	—	—	—	—	121.5	15.7

Note. The dioxane concentration was varied from 0 to 2.5 molar with a constant molar concentration of DDB or bromine and ether of 0.015.

TABLE 6

Influence of Excess of Dioxane Dibromide on the Process of Bromination of Phenetole

DDB 0.015		DDB 0.020		DDB 0.025		DDB 0.030	
T	*A*	*T*	*A*	*T*	*A*	*T*	*A*
3.2	29.5	2.4	39.7	2.4	47.9	2.8	58.8
20.6	28.4	12.7	38.4	11.7	46.3	11.1	56.1
55.2	26.5	27.2	36.75	21.3	44.85	19.5	54.3
90.5	24.5	62.4	33.95	30.0	43.65	34.3	52.2
119.8	24.3	91.0	32.60	60.1	40.4	63.0	48.65
151.7	23.3	121.1	30.6	90.2	37.65	92.7	46.0
180.0	22.3	150.5	28.95	121.1	35.9	122.3	43.9
209.0	21.75	180.4	27.7	150.5	34.4	179.4	40.95
238.7	21.15	300.2	21.1	180.0	32.9	299.1	36.3

Note. Constant phenetole concentration = 0.01 molar); the starting concentration of DDB varied between 0.01 and 0.03 molar.

TABLE 7

Influence of Excess of Phenetole on the Process of Its Bromination

E 0.01		E 0.015		E 0.02		E 0.03	
T	*A*	*T*	*A*	*T*	*A*	*T*	*A*
2.4	20.6	3.2	20.5	2.9	20.4	3.0	19.7
14.6	19.65	6.9	20.2	16.1	19.45	6.7	19.2
28.7	19.3	17.8	19.8	30.9	18.9	17.7	18.3
60.0	18.5	37.8	19.1	61.9	17.4	28.1	17.7
89.6	17.75	64.5	18.1	89.0	16.4	48.9	16.7
119.6	17.25	94.3	17.25	119.3	15.4	88.2	14.5
179.1	16.2	123.5	16.2	151.1	14.5	126.0	13.0
240.0	15.3	182.9	15.0	180.0	13.8	164.0	11.8
294.0	14.1	243.0	13.8	219.0	12.7	258.0	10.2

Note. Constant starting DDB concentration of 0.01 molar; the phenetole concentration ranged from 0.01 to 0.03 molar.

Symbols used in the tables. E is the molar concentration of the ether; D is the molar concentration of dioxane; T is the time elapsed since start of experiment (in min); A is the consumption of 0.01 N thiosulfate solution (in ml) per 10 ml of reaction mixture; HB is the molar concentration of hydrogen bromide at the start of reaction. All experiments were run at 25°.

TABLE 8

Influence of Hydrogen Bromide on the Process of Bromination of Phenetole

HB 0.0000		HB 0.0176		HB 0.088		HB 0.176	
T	*A*	*T*	*A*	*T*	*A*	*T*	*A*
2.3	27.1	2.7	28.35	2.4	28.65	2.2	27.7
15.9	25.9	17.7	25.6	8.1	26.4	6.6	25.55
38.6	24.0	31.7	23.3	20.0	22.9	14.9	21.8
48.0	23.9	43.1	22.25	34.4	19.5	31.0	17.1
58.2	23.2	59.6	20.65	45.2	17.8	48.1	14.1
78.1	22.45	73.4	19.45	75.7	14.1	68.3	11.8
91.0	21.75	91.4	18.05	93.6	12.8	90.5	10.2
105.2	21.2	116.9	16.65	106.1	12.0	108.8	9.0
121.3	20.5	150.3	14.8	122.8	11.25	120.3	8.4

Note. Concentrations of phenetole and DDB 0.015 molar; starting concentration of HB from 0 to 0.176 molar.*

* Due to the poor solubility of hydrogen bromide in benzene at 25°, it was used in dioxane solution.

SUMMARY

1. The bromination process is a third-order reaction and its rate is proportional to the square of the dioxane dibromide concentration and to the first power of the ether concentration.

2. Hydrogen bromide speeds up the process due to its protonizing influence on the hydrogen of the benzene ring.

3. The brominating activity of dioxane dibromide slightly surpasses that of bromine; this superiority is fully accounted for by the distance between the bromine atoms in the molecule of dioxane dibromide being slightly larger than the interatomic distance in the bromine molecule (different degree of polarization).

LITERATURE CITED

[1] A. E. Favorskii, Zhur. Russ. Khim. Obshchestva 38, 741 (1906).

[2] L. A. Yanovskaya, Doklady Akad. Nauk SSSR 71, 693 (1950); L. A. Yanovskaya, A. P. Terent'ev, and L. I. Belen'kii, Zhur. Obshchei Khim. 22, 1994 (1952); L. A. Yanovskaya and A. P. Terent'ev, Zhur. Obshchei Khim. 22, 1598 (1952); G. M. Kosolapoff, J. Am. Chem. Soc. 75, 3596 (1953); C. Price and C. Weaker, J. Am. Chem. Soc. 61, 3360 (1939).

[3] O. Hessel and J. Hvelslef, Acta Chem. Scand. 8, 873 (1954).

[4] Yu. V. Karyakin and I. I. Angelov, Pure Chemical Reagents [In Russian] (GKhI, 1955), p. 98.

[5] N. P. Kanyaev and E. A. Shilov, Zhur. Fiz. Khim. 13, 1563 (1939); Zhur. Obshchei Khim. 16, 95 (1946).

[6] C. K. Ingold, The Mechanism of Reactions and the Structure of Organic Compounds [Russian translation] (Foreign Lit. Press, 1959), p. 233.

ADDITION OF TROPYLIUM SALTS TO VINYL ETHERS

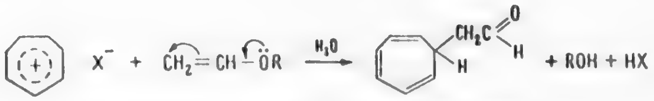
M. E. Vol'pin, I. S. Akhrem, and D. N. Kursanov

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 159-163, January, 1960

Original article submitted January 5, 1959

It is known that carbon – carbon double bonds react energetically with various electrophilic reagents. Olefins, for example, combine with facility with strong acids and with salts of a series of heavy metals.

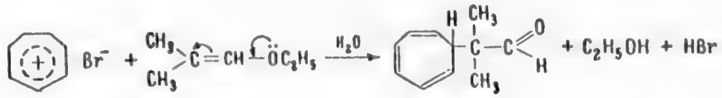
Tropylium salts, which are electrophilic reagents [1], might be expected to add on in similar fashion to double-bond compounds. However, the majority of compounds containing isolated or conjugated carbon-carbon double bonds (for example cycloheptatriene, methylcyclohexene) do not react with tropylium salts in the absence of catalysts. Similarly, tropylium salts do not react with olefins containing electron-accepting substituents (cinnamic acid, acrylic acid, acrylonitrile, allyl chloride). On the other hand, vinyl ethers react vigorously with tropylium salts [2]. The high reactivity of the double bond of vinyl ethers is due to the influence of the electron-donating ether group.



$X = Br, ClO_4$, $R = C_2H_5$, iso-C_3H_7, C_4H_9, $OCOCH_3$

Reaction of tropylium salts in water or aqueous alcohol with vinyl ethyl, vinyl isopropyl and vinyl n-butyl ethers and with vinyl acetate gives one and the same product – cycloheptatrienylacetaldehyde, irrespective of the nature of the alkyl radical of the vinyl ether and of the character of the anion of the tropylium salt.

Tropylium bromide similarly reacts with β,β-dimethylvinyl ethyl ether.



However, the latter reaction proceeds very much more slowly and with poorer yields than the reaction of tropylium salts with unsubstituted vinyl ethers.

Reaction of tropylium bromide with vinyl ethyl ether in anhydrous nitromethane leads to formation not of an aldehyde but of a bromine-containing substance. The latter is extremely unstable and decomposes on distillation. It could not be isolated pure; it is probably an α-bromoether.

$$C_7H_7^+Br^- + CH_2{=}CHOC_2H_5 \longrightarrow C_7H_7CH_2CH\begin{cases}Br\\OC_2H_5\end{cases}$$

When this reaction is performed in anhydrous alcohol, an acetal is formed together with the bromo product.

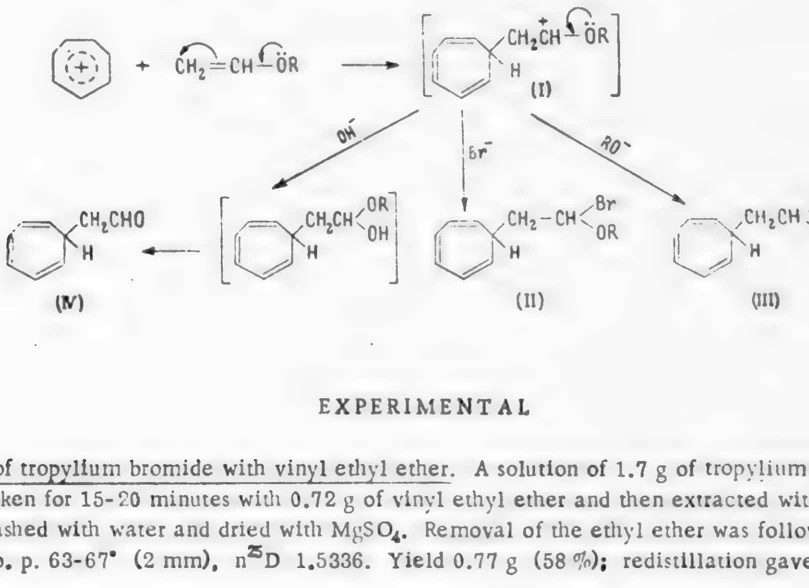
$$C_7H_7^+Br^- + CH_2{=}CHOC_2H_5 + C_2H_5OH \rightarrow C_7H_7CH_2CH(OC_2H_5)_2 + HBr.$$

Separation of the acetal is hindered, however, by the presence of the acid.

With the objective of obtaining acetals in the pure form, an attempt was made to react vinyl ethers with ditropyl ether $(C_7H_7)_2O$, i.e., under conditions excluding formation of an acid. In spite of the lability of the ether bond in ditropyl ether, this reaction does not go either in the cold or on heating. But introduction of even catalytic quantities of a tropylium salt (or acid) initiates vigorous reaction of the ditropyl ether with vinyl ethers. In anhydrous alcohol the reaction then gives a good yield of cycloheptatrienylacetaldehyde; the reaction with vinyl butyl ether in a medium of anhydrous n-butyl alcohol gives the di-n-butylacetal of cycloheptatrienylacetaldehyde; the reaction with vinyl isopropyl ether in anhydrous isopropyl alcohol gives the diisopropylacetal of cycloheptatrienylacetaldehyde. In all these cases, an ionic chain reaction is evidently involved in which the transmitter of the chain is the tropylium cation.

$$C_7H_7^+ + CH_2{=}CHOR + ROH \rightarrow C_7H_7CH_2CH(OR)_2^+ + H^+$$
$$\frac{1}{2}(C_7H_7)_2O + H^+ \rightarrow C_7H_7^+ + \frac{1}{2}H_2O$$

Consequently, tropylium salts react with vinyl ethers and do not react with olefins containing electron-accepting groups, while ditropyl ether (in absence of a tropylium salt) does not even enter into reaction with vinyl ethers. All this indicates that the mechanism of interaction of a tropylium salt with a vinyl ether involves preliminary action of the $C_7H_7^+$ ion on the double bond. We may suggest that an intermediate step in the reaction is formation of a carbonium ion of the type of (I); the latter in hydroxyl-free solvents is converted to the bromo-ether (II), in alcohol it is converted to the acetal (III), and in water to the aldehyde (IV).



EXPERIMENTAL

Reaction of tropylium bromide with vinyl ethyl ether. A solution of 1.7 g of tropylium bromide in 10 ml of water was shaken for 15-20 minutes with 0.72 g of vinyl ethyl ether and then extracted with ether. The ethereal extracts were washed with water and dried with $MgSO_4$. Removal of the ethyl ether was followed by collection of a fraction with b. p. 63-67° (2 mm), $n^{25}D$ 1.5336. Yield 0.77 g (58 %); redistillation gave cycloheptatrienylacetaldehyde.

B. p. 62° (2 mm), $n^{20}D$ 1.5340, d^{20}_4 1.0204, MR 40.87; Calc. 40.17.*

Found %: C 80.79, 80.63; H 7.46, 7.48. $C_9H_{10}O$. Calculated %: C 80.56; H 7.51.

The 2,4-dinitrophenylhydrazone of cycloheptatrienylacetaldehyde is a yellow powder; decomp. p. above 190° (from nitromethane).

* In all cases MR was calculated without correction for the 7-membered ring and the double-bond exaltation.

Dimedon derivative: colorless needles, m. p. 146.5° (from alcohol).

Found %: C 75.90, 75.41; H 8.14, 8.13. $C_{25}H_{32}O_4$. Calculated %: C 75.72; H 8.13.

Reactions of tropylium bromide and perchlorate with vinyl isopropyl ether, vinyl butyl ether and vinly acetate were carried out similarly [2].

Reaction of tropylium bromide with β,β-dimethylvinyl ethyl ether. To 2 g of β,β-dimethylvinyl ethyl ether [3] in 2 ml of alcohol was added a solution of 1.71 g of tropylium bromide in 10 ml of water. After 3 hours, the solution was extracted with ether. The ethereal extracts were washed with water and dried with $MgSO_4$. After the solvent had been driven off, 0.14 g (8.6 %) of unpurified cycloheptatrienylisobutyraldehyde was obtained.

B. p. 76-80° (3 mm), $n^{20}D$ 1.5201.

Literature data [4]: b. p. 74° (3 mm), $n^{20}D$ 1.5185.

2,4-Dinitrophenylhydrazone: m. p. 150°. A mixture with the 2,4-dinitrophenylhydrazone of cyclo heptatrienylisobutyraldehyde obtained by reaction of a tropylium salt with isobutyraldehyde [4] did not give a depression of melting point.

Reaction of ditropyl ether with vinyl ethers. 1. Diethylacetal of cycloheptatrienylacetaldehyde. To 1 g of ditropyl ether (b. p. 119-120° at 3 mm) in 10 ml of anhydrous alcohol was added 3 g of vinyl ethyl ether. Addition of a few milligrams of tropylium bromide was followed by self-heating of the solution, and after 15-20 minutes the reaction was at an end. For elimination of traces of bromine-containing product, a solution of sodium ethoxide in anhydrous alcohol was added until the mass was alkaline to phenolphthalein. Several milliliters of benzene were then added to the solution and the solvent was distilled off. There was obtained 1.5 g of diethylacetal of cycloheptatrienylacetaldehyde (72%) with b. p. 102° (5 mm), $n^{20}D$ 1.4876.

To ditropyl ether (without previous distillation), prepared by treatment of 3.8 g of tropylium perchlorate with sodium bicarbonate in water followed by extraction with ether, were added a solution of 1.5 g of vinyl ethyl ether in 10 ml of anhydrous alcohol and a catalytic quantity of tropylium salt. Reaction was completed in 20 to 25 minutes. Treatment of the reaction solution with a little sodium ethoxide in alcohol and distillation of the solvent gave 2.44 g of acetal (66% calculated on the tropylium perchlorate).

B. p. 92-93° (2 mm), $n^{20}D$ 1.4882, d^{20}_4 0.9462, MR 63.40; Calc. 61.93.

Found %: C 74.41, 74.72; H 9.62, 9.62. $C_{13}H_{20}O_2$. Calculated %: C 74.96; H 9.68.

2. Dibutylacetal of cycloheptatrienylacetaldehyde. The above procedure was employed for reaction of ditropyl ether (from 4 g of tropylium perchlorate) and 1 g of vinyl butyl ether in 5 ml of anhydrous butyl alcohol in presence of tropylium salt to give 3.96 g of acetal (75% calculated on the tropylium perchlorate).

B. p. 130° (3 mm), $n^{20}D$ 1.4806, d^{20}_4 0.8188, MR 81.83; Calc. 80.39.

Found %: C 77.14, 77.31; H 10.77, 10.79. $C_{17}H_{28}O_2$. Calculated %: C 77.22; H 10.67.

3. Diisopropylacetal of cycloheptatrienylacetaldehyde. Similarly, reaction of 2.85 g of ditropyl ether in presence of tropylium salt with 0.7 g of vinyl isopropyl ether in 5 ml of anhydrous isopropyl alcohol gave 1.61 g of acetal (75.6% calculated on the tropylium perchlorate), b. p. 96-100° (3 mm), $n^{20}D$ 1.4856.

Found %: C 76.12, 76.26; H 9.71, 9.92. $C_{15}H_{24}O_2$. Calculated %: C 76.22; H 10.23.

SUMMARY

1. It was shown that tropylium salts add on at the activated double bond in vinyl ethers with facility to give the corresponding aldehydes. Unactivated double bonds, or double bonds to which are attached electron-accepting substituents, do not combine with tropylium salts.

2. In presence of small quantities of a tropylium salt or an acid, ditropyl ether adds on to vinyl ethers. In this manner diethyl-, dibutyl and diisopropylacetals of cycloheptatrienylacetaldehyde were prepared.

LITERATURE CITED

[1] W. E. Doering and L. H. Knox, J. Am. Chem. Soc. 76, 3203 (1954); 79, 352 (1957).

[2] D. N. Kursanov, M. E. Vol'pin, and I. S. Akhrem, Doklady Akad. Nauk SSSR 120, 531 (1958).

[3] A. M. Butlerov, Zhur. Russ. Khim. Obshchestva 2, 192 (1870).

[4] M. E. Vol'pin, I. S. Akhrem, and D. N. Kursanov, Zhur. Obshchei Khim. 29, 2855 (1959).

SYNTHESIS OF 3-SUBSTITUTED QUINUCLIDINES

E. E. Mikhlina and M. V. Rubtsov

S. Ordzhonikidze All-Union Scientific Research Chemicopharmaceutical Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 163-171, January, 1960

Original article submitted January 2, 1959

Most of the quinuclidine derivatives that have been described and studied pharmacologically are substituted in the 2-position and were synthesized mainly from the available quinuclidine-2-carboxylic acid [1, 2].

Derivatives of quinuclidine with substituents in the 3-position have been studied in less detail. In this series only a few esters and urethanes of 3-hydroxynuclidine have been prepared for biological investigation [3, 4].

In the present communication, we describe the synthesis and the results of pharmacological investigation of a series of esters of 3-hydroxyquinuclidine and also esters of 3-(γ-hydroxypropoxy)quinuclidine and 3-(γ-thiopropoxy)quinuclidine. As a starting material for the synthesis of these compounds, we used 3-hydroxyquinuclidine prepared from the available quinuclidone-3.

Reduction of the quinuclidone-3 to 3-hydroxyquinuclidine was accomplished with lithium aluminum hydride in ether solution [5], sodium borohydride in methyl alcohol solution, or catalytically in the presence of platinum (as described by Adams) at room temperature.

3-Hydroxyquinuclidine was esterified with the aid of the acid chlorides in benzene or chloroform solution. In most cases, the reaction in chloroform solution proceeded with good yields.

(I) (II)

The physical properties of the esters (II) prepared in this way and the results of analyses and values of R are given in the table.

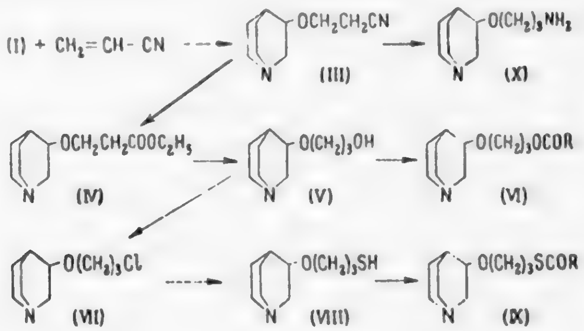
By reduction of 3-(p-nitrobenzoyloxy) quinuclidine in the presence of Raney nickel catalyst, 3-(p-aminobenzoyloxy) quinuclidine was synthesized, and by reduction in the presence of platinum, 3-(p-aminocyclohexanoyloxy) quinuclidine was obtained; hydrogenation of the ester of 3-hydroxyquinuclidine and cinnamic acid yielded 3-(β-phenylpropionoxy) quinuclidine.

The syntheses of 3-(γ-hydroxypropoxy) quinuclidine, 3-(γ-thiopropoxy)-quinuclidine, and their esters were carried out by the method described below.

When 3-hydroxyquinuclidine was reacted with acrylonitrile in the presence of a catalyst (30% potassium hydroxide solution in methyl alcohol), 3-(β-cyanoethoxy)quinuclidine (III) was produced. This compound was easily reduced with the aid of lithium aluminum hydride to 3-(γ-aminopropoxy) quinuclidine (X).

Conversion of compound (III) to 3-(β-carboethoxyethoxy) quinuclidine (IV) was possible in three ways: a) by prolonged heating of the nitrile (III) with anhydrous alcohol and concentrated sulfuric acid; b) by

hydrolysis of the nitrile (III) to 3-(β-carboxyethyloxy) quinuclidine with subsequent esterification of the acid; c) by passing a current of dry hydrogen chloride into a boiling solution of the nitrile (III) in anhydrous alcohol. The yield of the ester (IV) in all these modifications was about 60-75%; however, "c" was preferable, because in that case, the reaction went considerably more quickly and the ester (IV) obtained was not contaminated with the starting nitrile (III), which was observed when the synthesis was carried out by method "a".

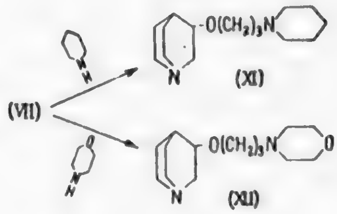


(VI) and (IX): a) $R=CH_3$; b) $R=C_6H_5$; c) $R=NO_2C_6H_4$; d) $R=(C_6H_5)_2CH$

In accordance with the above schematic diagram, 3-(β-carboethoxyethoxy) quinuclidine (IV) was reduced with lithium aluminum hydride to 3-(γ-hydroxypropoxy) quinuclidine (V). Upon heating the alcohol (V) with the acid chlorides in benzene solution, the esters (VI) were obtained.

To prepare 3-(γ-mercaptopropoxy) quinuclidine (VIII), the hydroxy group in compound (V) was replaced by chlorine by heating (V) with thionyl chloride. The 3-(γ-chloropropoxy) quinuclidine (VII) obtained was converted to 3-(γ-mercaptopropoxy) quinuclidine (VIII) by reaction with thiourea and then with alkali. The thioesters (IX) were synthesized by reacting the mercaptan (VIII) with the acid chlorides. The reaction was carried out in ether at room temperature.

Besides converting the chloride (VII) to the mercaptan (VIII), the possibility of replacing chlorine in compound (VII) by a dialkylamino group was investigated. For this purpose, the chloride (VII) was subjected to heating with piperidine, morpholine, and diethylamine. In the first two instances the corresponding 3-[γ-(N-piperidino) propoxy] quinuclidine (XI) and 2-[γ-(N-morpholino) propoxy] quinuclidine (XII) were obtained.



But along with compounds (XI) and (XII), the formation of a material that appeared to be a polymer of the chloride (VII) was observed in the reaction of the chloride with piperidine and morpholine. This material was the sole product from the reaction of (VII) with diethylamine.

In a pharmacological investigation of the materials prepared, which was carried out in the division of pharmacology of our institute, by K. A. Zaitseva under the direction of M. D. Mashkovskii, it was found that some esters of 3-hydroxynuclidine are very active pharmacologically. Thus, 3-acetoxyquinuclidine has a very strong cholinomimetic action, with its activity approaching that of proserine; 3-benzoyloxyquinuclidine showed a significant hypotensive effect in an experiment.

EXPERIMENTAL

3-Hydroxyquinuclidine (I). a) To a solution of 10 g of sodium borohydride in 70 ml of methyl alcohol was added with stirring a solution of 10 g of quinuclidone-3 in 30 ml of methyl alcohol. The reaction mixture was stirred at room temperature for 3 hours, then the alcohol was distilled off in vacuo, and the 3-hydroxyquinuclidine was extracted from the residue with hot benzene. The benzene solution was dried with sodium sulfate and evaporated, yielding 7.8 g (76.8%) of 3-hydroxyquinuclidine. M. p. 218-220° [5].

b) A mixture of 20 g of quinuclidone-3, 200 ml of anhydrous alcohol, and 0.3 g of platinic oxide (Adams) was shaken with hydrogen at room temperature and a hydrogen pressure of 20-30 cm of water. After 1 mole of hydrogen had been absorbed, the platinum black was filtered off, the alcoholic solution was evaporated in vacuo, the residue was ground with ether, and the 3-hydroxyquinuclidine was filtered by suction. Yield 19.4 g (95.5%), m. p. 218-220°.

3-Acetoxyquinuclidine. Two g of 3-hydroxyquinuclidine, 4 ml of acetyl chloride, and 20 ml of benzene were heated at boiling for 9 hours. The benzene solution was treated with 20 ml of 50% potassium carbonate solution, the benzene was separated off, and the alkaline solution was extracted with ether. The combined ether and benzene extracts were dried with potassium carbonate, the solvents were distilled off, and the residue was distilled in vacuo. The yield was 1.8 g (67.7%) of 3-acetoxyquinuclidine. It was a colorless, mobile liquid, readily soluble in organic solvents, but poorly soluble in water. B. p. 73-74° (0.4 mm).

3-Phenoxyacetoxyquinuclidine. A solution of 3 g of 3-hydroxyquinuclidine in 15 ml of anhydrous chloroform and 8.06 g of phenoxyacetyl chloride in 15 ml of chloroform were mixed at 0° and left at room temperature for 24 hours. Then the mixture was boiled for 18 hours, evaporated in vacuo, and the residue was dissolved in 20 ml of 3% hydrochloric acid and extracted with ether to remove the neutral substances. The hydrochloric acid solution was treated with a 50% solution of potassium carbonate, extracted with ether, and the ether extract was dried with potassium carbonate, evaporated in vacuo, and the residue was distilled. The yield was 5.5 g (89%) of 3-phenoxyacetoxyquinuclidine.

A hydrochloride was obtained with m. p. 165-167° (from a mixture of acetone and alcohol). The esters shown in the table were prepared in a similar manner.

3-(p-Aminobenzoyloxy) quinuclidine. To a solution of 2.1 g of 3-(p-nitrobenzoyloxy) quinuclidine in 60 ml of anhydrous alcohol was added 2 g of nickel catalyst, and the mixture was shaken with hydrogen at room temperature. The necessary amount of hydrogen (570 ml) was absorbed in 1.5 hours. The catalyst was filtered off, the alcohol was distilled off in vacuo, and the oily residue was crystallized by grinding with ether. The yield was 1.3 g (69.5%) of 3-(p-aminobenzoyloxy) quinuclidine in the form of colorless crystals, readily soluble in alcohol, acetone, and chloroform, and more difficultly soluble in benzene and ether. M. p. 137-139° (from benzene).

Found %: C 68.52; H 7.58; N 11.20. $C_{14}H_{18}O_2N_2$. Calculated %: C 68.29; H 7.32; N 11.38.

3-(p-Aminocyclohexanoyloxy) quinuclidine. 3.05 g of 3-(p-nitrobenzoyloxy) quinuclidine, 50 ml of anhydrous alcohol, 2 ml of 20% alcoholic solution of hydrogen chloride, and 0.1 g of platinic oxide were shaken with hydrogen at room temperature and a pressure of 20-30 cm of water. After the absorption of hydrogen ceased (1460 ml), 5 ml of water was added to the reaction mixture, the platinum black was filtered off, the alcohol was distilled off in vacuo, and the residue was treated with a 50% solution of potassium carbonate and extracted with ether. The ether solution was dried with potassium carbonate and evaporated in vacuo, and the material obtained was distilled. The yield was 2.1 g (85.5%), b. p. 159-161° (0.3 mm). Colorless viscous liquid, readily soluble in organic solvents, poorly soluble in water.

Found %: C 66.50; H 9.56. $C_{14}H_{24}O_2N_2$. Calculated %: C 66.66; H 9.53.

3-(β-Phenylpropionoxy) quinuclidine. 3 g of the hydrochloride of the ester of 3-hydroxyquinuclidine and cinnamic acid, 80 ml of anhydrous alcohol, and 0.1 g of platinic oxide were shaken with hydrogen at room temperature. After 1 mole of hydrogen had been absorbed, the platinum black was filtered off and the alcohol was evaporated in vacuo. The yield amounted to 2.8 g (93.2%) of the hydrochloride of 3-(β-phenylpropionoxy)-quinuclidine. Colorless crystals, readily soluble in water and alcohol, insoluble in ether. M. p. 138-140°.

Esters of 3-(γ-Hydroxypropoxy) quinuclidine

Expt. No.	R	Yield (in %)	Boiling point (pressure in mm)	Melting point of hydrochloride	Empirical formula	% C		% H		% N		% Cl	
						found	calc.	found	calc.	found	calc.	found	calc.
1	CH_3	84	73— 74° (0.4)	173—175°	$C_9H_{15}O_2N \cdot HCl$	52.66	52.50	7.81	7.78	6.60	6.82	17.04	17.30
2	C_2H_5	56.6	74— 76 (0.3)	174—176	$C_{10}H_{17}O_2N \cdot HCl$	—	—	—	—	6.26	6.38	16.47	16.17
3	C_3H_7	58.2	84— 85 (0.3)	175—177	$C_{11}H_{19}O_2N \cdot HCl$	—	—	—	—	5.94	6.00	15.42	15.25
4	iso- C_4H_9	72.5	88— 90 (0.3)	180—182	$C_{12}H_{21}O_2N \cdot HCl$	—	—	—	—	5.34	5.66	14.26	14.36
5	$CH_2{=}CH{-}(CH_2)_8$ *	73.7	227—230 (0.7)	—	$C_{18}H_{31}O_2N$	73.72	73.72	10.52	10.58	4.82	4.78	—	—
6	CH_3OCH_2 *	65.5	101—104 (0.4)	172—174	$C_{10}H_{17}O_3N$	—	—	—	—	6.89	7.03	—	—
7	$C_2H_5SCH_2$ *	77.7	118—119 (0.3)	—	$C_{11}H_{19}O_2NS$	—	—	—	—	5.85	6.11	13.82**	13.96**
8	C_6H_5	71.5	148—150 (0.3)	238—240	$C_{14}H_{17}O_2N \cdot HCl$	—	—	—	—	5.23	5.23	13.49	13.27
9	$4\text{-}NO_2C_6H_4$	83.5	133—135 ***	256—258	$C_{14}H_{16}O_4N_2 \cdot HCl$	—	—	—	—	9.06	8.96	10.88	11.34
10	$4\text{-}BrC_6H_4$	73.5	—	243—245 ****	$C_{14}H_{16}O_2NBr \cdot HCl \cdot H_2O$	46.55	46.10	5.35	5.21	4.29	3.94	—	—
11	$4\text{-}ClC_6H_4$	88.5	—	198—200	$C_{14}H_{16}O_2NCl \cdot HCl$	—	—	—	—	4.64	4.74	23.51	23.56
12	$C_6H_5OCH_2$	89	180 (1)	165—167	$C_{15}H_{19}O_3N \cdot HCl$	—	—	—	—	4.79	4.70	11.49	11.93
13	$C_6H_5CH_2$ *	73.8	151—152 (0.3)	—	$C_{15}H_{19}O_2N$	33.18	73.47	7.81	7.75	—	—	—	—
14	$C_6H_5CH{=}CH_2$	86.5	—	187—189	$C_{16}H_{19}O_2N \cdot HCl$	—	—	—	—	5.15	4.77	12.65	12.09
15	$3,4,5\text{-}(OCH_3)_3C_6H_2$ *	44	67— 70 ***	203—205	$C_{17}H_{23}O_5N$	63.91	64.00	7.39	7.18	4.59	4.39	—	—
16	$3\text{-}C_5H_4N$	73.2	141—142 (0.35)	231—233 *****	$C_{13}H_{16}O_2N_2 \cdot 2HCl$	—	—	—	—	9.08	9.17	23.00	23.28
17	$4\text{-}C_5H_4N$	50.2	149—150 (0.5)	238—240 *****	$C_{13}H_{16}O_2N_2 \cdot 2HCl$	—	—	—	—	9.13	9.17	23.25	23.28

* Analysis and empirical formula given for the base.
** Analytical data for sulfur.
*** Melting point of base.
**** Crystallizes with 1 molecule of water.
***** Melting point and analysis given for dihydrochloride.

Found %: N 4.80, 4.58; Cl 12.11, 11.91. $C_{16}H_{21}O_2N \cdot HCl$. Calculated %: N 4.76; Cl 12.01.

3-(β-Cyanoethoxy)quinuclidine (III). To a suspension of 20 g of 3-hydroxyquinuclidine in 100 ml of anhydrous dioxane was added 3.2 ml of a 30% solution of potassium hydroxide in methyl alcohol, and then 32 ml of acrylonitrile was added with stirring over a period of 15 minutes. During this process, the temperature of the mixture rose to 30-33°. The reaction mixture was heated for 4 hours at 60-65°, cooled to room temperature, and diluted with 100 ml of benzene. The acrylonitrile polymer that separated out was filtered off and the mother liquor was evaporated in vacuo. The residue was dissolved in 40 ml of 10% hydrochloric acid, the acid solution was extracted with ether to remove the neutral substances, then made alkaline with 50% potassium carbonate solution and again extracted with ether. The ether solution obtained by extraction of the alkaline mixture was dried with potassium carbonate and evaporated in vacuo, and the residue was distilled. The yield was 21.6 g (76.3%) of 3-(β-cyanoethoxy) quinuclidine in the form of a colorless viscous liquid, readily soluble in organic solvents, poorly soluble in water. B. p. 114-115° (0.5 mm), $n^{19}D$ 1.4903.

Found %: C 66.20, 66.39; H 9.14, 9.02; N 15.76, 15.81. $C_{10}H_{16}ON_2$. Calculated %: C 66.67; H 8.89; N 15.55.

3-(β-Carboethoxyethoxy)quinuclidine (IV). a) 1.35 g of 3-(β-cyanoethoxy) quinuclidine, 4 ml of anhydrous alcohol, and 2 g of concentrated sulfuric acid were heated at boiling for 18 hours. The reaction mixture was poured, with cooling, into 7 ml of water, 12 ml of 50% potassium carbonate solution was added to the acid solution, and the resulting alkaline solution was extracted with ether. The ether extract was dried with potassium carbonate and evaporated in vacuo, and the residue was distilled. The yield was 1.22 g (70.5%) of 3-(β-carboethoxyethoxy) quinuclidine in the form of a colorless viscous liquid, readily soluble in water and organic solvents. B. p. 116-117° (0.6 mm), $n^{17}D$ 1.4740.

Found %: C 62.95; H 9.07; N 6.09. $C_{12}H_{21}O_3N$. Calculated %: C 63.47; H 9.24; N 6.17.

b) 18.46 g of 3-(β-cyanoethoxy)quinuclidine, 360 ml of glacial acetic acid, and 180 ml of concentrated hydrochloric acid were heated at boiling for 20 hours. The solution was evaporated on a steam bath. The residue, which was a mixture of the hydrochloride of 3-(β-carboxyethoxy)quinuclidine and ammonium chloride, was transferred to a flask and dried by adding anhydrous alcohol and subsequently distilling it off in vacuo. This operation was repeated 3-4 times. Then 150 ml of a 12% alcoholic solution of hydrogen chloride was added to the reaction mixture and it was heated at the boiling point of the alcohol for 3 hours. The alcoholic solution was evaporated in vacuo and the residue was treated with a 50% solution of potassium carbonate and extracted with ether. The dried ether solution was evaporated and the residue was distilled. The yield was 17.2 g (73.8%) of 3-(β-carboethoxyethoxy) quinuclidine. B. p. 116-117° (0.6 mm), $n^{17}D$ 1.4740.

c) 21.6 g of 3-(β-cyanoethoxy) quinuclidine was dissolved in 105 ml of anhydrous alcohol and a current of dry hydrogen chloride was passed through the alcoholic solution for 4 hours while the solution was boiled and stirred. The reaction mixture was kept for 20 hours at room temperature, the ammonium chloride was filtered off with suction, the alcohol solution was evaporated in vacuo, and the residue was treated with 50% potassium carbonate solution and extracted with ether. The yield was 16.6 g (60.8%) of 3-(β-carboethoxyethoxy)-quinuclidine. B. p. 116-117° (0.6 mm), $n^{17}D$ 1.4740.

3-(γ-Aminopropoxy)quinuclidine (X). To a suspension of 0.53 g of lithium aluminum hydride in 25 ml of anhydrous ether was added with stirring a solution of 1 g of 3-(β-cyanoethoxy)quinuclidine in 20 ml of anhydrous ether. The reaction mixture was heated for 5 hours at the boiling point of the ether, cooled, and treated with 1 ml of water. The inorganic salts were filtered off with suction and washed with ether, and the ether extracts were dried with potassium carbonate, evaporated, and the residue was distilled in vacuo. The yield was 0.65 g (63.5%) of 3-(γ-aminopropoxy)quinuclidine. The product was a colorless viscous liquid, readily soluble in water and organic solvents. B. p. 111-112° (0.5 mm), $n^{17}D$ 1.500.

Found %: N 14.91, 14.86. $C_{10}H_{20}ON_2$. Calculated %: N 15.21.

3-(γ-Hydroxypropoxy) quinuclidine (V). 11.38 g of 3-(β-carboethoxyethoxy)quinuclidine was reduced with 2.9 g of lithium aluminum hydride in 170 ml of ether by the method described in the previous experiment. The yield was 8.83 g (95%) of 3-(γ-hydroxypropoxy)quinuclidine in the form of a viscous colorless liquid, readily soluble in water and organic solvents. B. p. 122-124° (0.5 mm), $n^{17}D$ 1.4973.

Found %: C 64.57; H 10.66. $C_{10}H_{19}O_2N$. Calculated %: C 64.86; H 10.28.

3-(γ-Acetoxypropoxy)quinuclidine (VIa). To a solution of 2.86 g of 3-(γ-hydroxypropoxy)quinuclidine in 25 ml of anhydrous benzene was added 2.42 g of acetyl chloride and the mixture was heated at boiling for 8 hours. To the cooled solution was added 20 ml of 50% potassium carbonate solution, the benzene layer was separated off, and the alkaline solution was further extracted with ether. The extracts were dried with potassium carbonate, the solvents were distilled off, and the residue was distilled in vacuo. The yield was 2.7 g (77.2%) of 3-(γ-acetoxypropoxy)quinuclidine. The product was a colorless mobile liquid, readily soluble in organic solvents, poorly soluble in water. B. p. 117-118° (0.5 mm).

Found %: C 63.13; H 9.39. $C_{12}H_{21}O_3N$. Calculated %: C 63.44; H 9.24.

The hydrochloride formed colorless hygroscopic crystals, m. p. 95-100°.

3-(γ-Benzoyloxypropoxy)quinuclidine (VIb). 2 g of 3-(γ-hydroxypropoxy)quinuclidine, 3.04 g of benzoyl chloride, and 20 ml of anhydrous benzene were heated at boiling for 6 hours. To the cooled reaction mixture was added 10 ml of 3% hydrochloric acid and the acid solution was extracted with benzene to remove the neutral substances. Then the hydrochloric acid solution was treated with 50% potassium carbonate solution and extracted with ether. From the ether solution 3 g (95.6%) of 3-(γ-benzoyloxypropoxy)quinuclidine was obtained in the form of a colorless mobile liquid, readily soluble in organic solvents, insoluble in water. B. p. 163-164° (0.3 mm).

Found %: C 70.31; H 7.93; N 5.06. $C_{17}H_{23}O_3N$. Calculated %: C 70.48; H 7.95; N 4.85.

The hydrochloride formed colorless crystals. M. p. 117-120° (from a mixture of alcohol and ether).

Found %: N 4.32; Cl 10.90. $C_{17}H_{23}O_3N \cdot HCl$. Calculated %: N 4.30; Cl 10.89.

3-(γ-Diphenylacetoxypropoxy)quinuclidine (VId). 2 g of 3-(γ-hydroxypropoxy)quinuclidine, 3 g of diphenylacetyl chloride, and 20 ml of anhydrous benzene were boiled for 3 hours. The reaction mixture was treated as described in the preceding experiment. The yield was 2.3 g (56%) of the ester in the form of a viscous colorless liquid, readily soluble in organic solvents, insoluble in water. B. p. 232-233° (0.35 mm).

Found %: C 75.84; H 7.67; N 3.70. $C_{24}H_{29}O_3N$. Calculated %: C 76.00; H 7.65; N 3.69.

3-[γ-(p-Nitrobenzoyloxy)propoxy] quinuclidine (VIc). To a solution of 1.5 g of 3-(γ-hydroxypropoxy)-quinuclidine in 15 ml of anhydrous benzene was added 1.8 g of p-nitrobenzoyl chloride. When the reagents were mixed, an initial evolution of heat occurred and a precipitate separated out. The reaction mixture was heated for 4 hours at boiling, cooled, and the precipitate was filtered off, washed on the filter with benzene, and recrystallized from 12 ml of anhydrous alcohol. The yield was 2.55 g (85%) of the hydrochloride of 3-[γ-(p-nitrobenzoyloxy)propoxy] quinuclidine. The product formed colorless crystals, readily soluble in water, less soluble in alcohol, insoluble in benzene and ether. M. p. 159-161°.

Found %: Cl 9.41, 9.44; N 7.22, 7.70. $C_{17}H_{22}O_5N_2 \cdot HCl$. Calculated %: Cl 9.58; N 7.55.

3-(γ-Chloropropoxy)quinuclidine (VII). To a solution of 2.2 g of 3-(γ-hydroxypropoxy)quinuclidine in 20 ml of anhydrous alcohol was added a 20% alcoholic solution of hydrogen chloride until there was an acid reaction to congo. Then the alcohol was distilled off in vacuo, 30 ml of anhydrous benzene and 15 ml of thionyl chloride were added to the oily residue, which was the hydrochloride of 3-(γ-hydroxypropoxy)quinuclidine, and the mixture was heated at 60-65° for 3 hours. The solution was evaporated in vacuo and 2.6 g (91.2 %) of the hydrochloride of 3-(γ-chloropropoxy)quinuclidine was obtained in the form of colorless hygroscopic crystals, readily soluble in water and alcohol, more difficultly soluble in acetone, and insoluble in ether and benzene. M. p. 128-130° (from acetone).

Found %: Cl 29.02; N 5.90. $C_{10}H_{18}ONCl \cdot HCl$. Calculated %: Cl 29.58; N 5.83.

3-[γ-(N-Piperidino)propoxy)quinuclidine] (XI). A solution of 1 g of the hydrochloride of 3-(γ-chloro-propoxy)quinuclidine and 1.42 g of piperidine in 8 ml of anhydrous alcohol was heated at boiling for 5 hours. The solution was evaporated in vacuo and the residue was treated with 50% potassium carbonate solution and extracted with ether. The ether solution was dried with sodium sulfate, the ether was distilled off, and the residue was distilled in vacuo. The yield was 0.37 g (35.2%) of 3-[γ-(N-piperidino)propoxy]quinuclidine. The product was a greenish mobile liquid with a sharp amine odor, soluble in water and in organic solvents. B. p. 141-143° (0.4 mm).

Found %: C 71.07; H 11.24; N 10.95. $C_{15}H_{28}ON_2$. Calculated %: C 71.43; H 11.11; N 11.11.

3-[γ-(N-Morpholino)propoxy]quinuclidine (XII). A solution of 2 g of the hydrochloride of 3-(γ-chloropropoxy) quinuclidine and 4.35 g of morpholine in 16 ml of anhydrous alcohol was heated at boiling for 9 hours. The reaction mixture was treated as described in the preceding experiment. The yield was 1 g (47.2%) of a colorless mobile liquid, readily soluble in water and organic solvents. B. p. 141° (0.4 mm).

Found %: N 11.20. $C_{14}H_{26}O_2N_2$. Calculated %: N 11.02.

3-(γ-Mercaptopropoxy)quinuclidine (VIII). A solution of 6.62 g of the hydrochloride of 3-(γ-chloropropoxy)quinuclidine and 2.1 g of thiourea in 33 ml of water was boiled for 6 hours. To the cooled solution was added 2.2 g of solid sodium hydroxide and the mixture was heated on a boiling water bath for 1 hour. The reaction mixture was saturated with sodium chloride, extracted with ether, the ether extract was dried with sodium sulfate and evaporated, and the residue was distilled in vacuo. The yield was 4.32 g (78%) of 3-(γ-mercaptopropoxy)quinuclidine in the form of a colorless mobile liquid with a sharp odor, readily soluble in organic solvents and water. B. p. 118-120° (1 mm), $n^{18}D$ 1.518.

Found %: N 7.21; S 15.83. $C_{10}H_{19}ONS$. Calculated %: N 6.96; S 15.92.

3-(γ-Acetylthiopropoxy)quinuclidine (IXa). To a solution of 1.5 g of 3-(γ-mercaptopropoxy)quinuclidine in 20 ml of anhydrous ether was added with cooling and stirring a solution of 0.9 g of acetyl chloride in 10 ml of ether. The reaction mixture was kept at room temperature for 5 hours, then the filtrate was drawn off with suction and the precipitate was washed with ether and dried. The yield was 2 g (95.5%) of the hydrochloride of 3-(γ-acetylthiopropoxy)quinuclidine. The product formed colorless crystals, readily soluble in water and alcohol, more difficultly soluble in acetone, insoluble in ether. M. p. 124-127° (from acetone).

Found %: Cl 12.70; S 11.38. $C_{12}H_{21}O_2NS \cdot HCl$. Calculated %: Cl 12.70; S 11.45.

3-(γ-Benzoylthiopropoxy)quinuclidine (IXb). From 1.65 g of 3-(γ-mercaptopropoxy)quinuclidine, 1.27 g of benzoyl chloride, and 20 ml of ether we obtained 2.5 g (89%) of the hydrochloride of the ester, in the manner described above. The product formed colorless crystals with m. p. 156-158° (from a mixture of acetone and alcohol).

Found %: Cl 10.38; S 9.16. $C_{17}H_{23}O_2NS \cdot HCl$. Calculated %: Cl 10.39; S 9.37.

3-(γ-Diphenylacetylthiopropoxy)quinuclidine (IXd). 1.5 g of 3-(γ-mercaptopropoxy)quinuclidine, 2.06 g of diphenylacetyl chloride, and 30 ml of anhydrous ether were treated as in the preceding experiments. The yield was 2.9 g (90.2%) of the hydrochloride of the ester. The product formed colorless crystals with m. p. 71-74°.

Found %: S 7.65. $C_{24}H_{29}O_2NS \cdot HCl$. Calculated %: S 7.41.

3-[γ-(p-Nitrobenzoylthio)propoxy]quinuclidine (IXc). From 1.32 g of 3-(γ-mercaptopropoxy)-quinuclidine, 1.46 g of p-nitrobenzoyl chloride, and 20 ml of anhydrous ether we obtained 2.3 g (90.5%) of the hydrochloride of the ester. The product formed colorless crystals with m. p. 168-170°.

Found %: Cl 9.48. $C_{17}H_{22}O_4N_2S \cdot HCl$. Calculated %: Cl 9.18.

SUMMARY

The synthesis of esters of 3-hydroxyquinuclidine, 3-(γ-hydroxypropoxy)quinuclidine, and 3-(γ-mercaptopropoxy)quinuclidine has been described.

Pharmacological investigation of the compounds prepared disclosed that the most active were 3-acetoxyquinuclidine (cholinomimetic action) and 3-benzoyloxyquinuclidine (hypotensive action).

LITERATURE CITED

[1] M. V. Rubtsov, E. S. Nikit-skaya and V. S. Usovskaya, Zhur. Obshchei Khim. 26, 130 (1956).*

[2] E. E. Nikitskaya, V. S. Usovskaya, and M. V. Rubtsov, Zhur. Obshchei Khim. 28, 161 (1958).*

[3] L. H. Sternbach and S. Keiser, J. Am. Chem. Soc. 74, 2219 (1952).

[4] Fed. Republic, German Patent 931,653 (1955).

[5] L. H. Sternbach and S. Keiser, J. Am. Chem. Soc. 74, 2215 (1952).

* Original Russian pagination. See C.B. Translation.

BICYCLIC SYSTEMS BASED ON 2,6-LUTIDINE

III. N-DERIVATIVES OF 3,9-OXAZABICYCLO-(3,3,1)-NONANE

E.S. Nikit-skaya, V.S. Usovskaya, and M. V. Rubtsov

S. Ordzhonikidze All-Union Scientific Research Chemicopharmaceutical Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 171-182, January, 1960

Original article submitted January 21, 1959

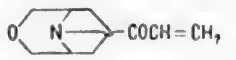
In a previous communication [1] we have described the synthesis of a new bicyclic compound, 3,9-oxazabicyclo-(3,3,1)-nonane, and a series of its N-derivatives.

A pharmacological study of these compounds, carried out in the division of pharmacology by P. M. Dozortseva, has shown that they affect the cholinoreactive systems of the organism. The simplest representatives of this series, the hydrochlorides of 3,9-oxazabicyclo-(3,3,1)-nonane and 9-methyl-3,9-oxazabicyclo-(3,3,1)-nonane, exerted a stimulating effect on the ganglions. As the weight of the molecule increased, the compounds acquired a ganglion-blocking property. The quaternary compounds of this series showed elements of a curare-like effect.

For a further study of the pharmacological activity of this series of compounds, we have synthesized acyl and alkyl derivatives of 3,9-oxazabicyclo-(3,3,1)-nonane (I), including compounds containing in the alkyl and acyl radicals such pharmacologically active heterocyclic systems as phenothiazine, quinosolone, morpholine, etc.

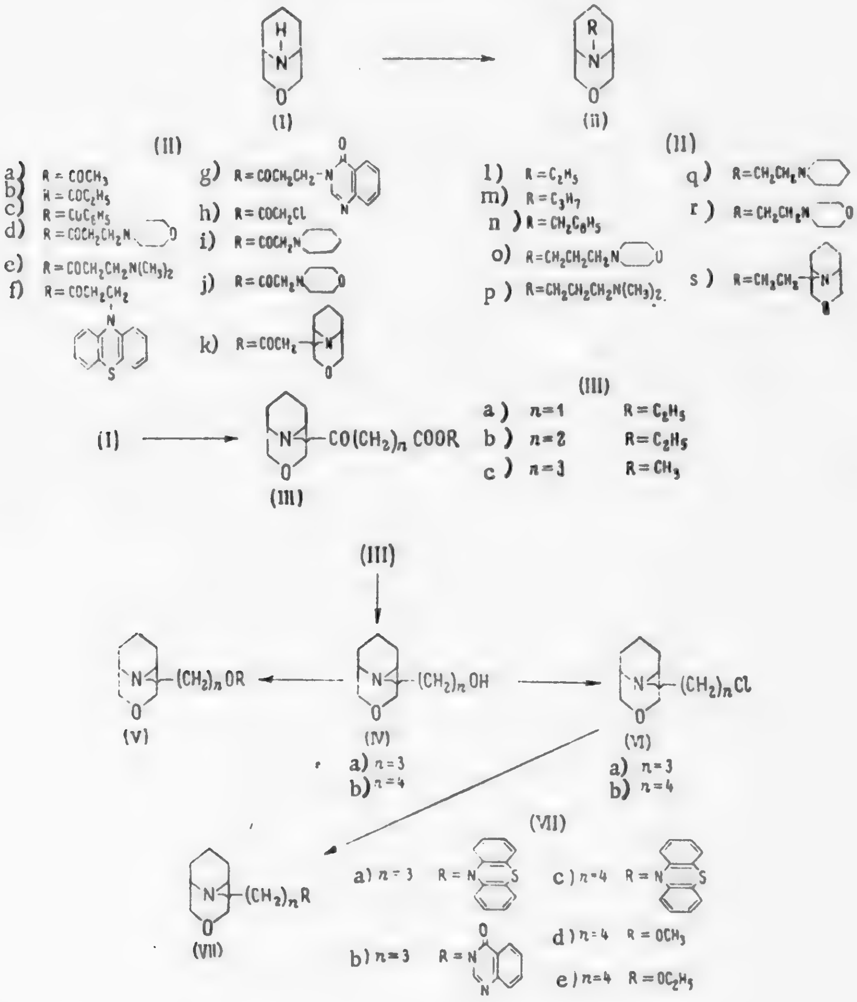
In order to synthesize the 9-ethyl-, (II, l), 9-propyl-, (II, m), and 9-benzyl, (II, n), derivatives of 3,9-oxazabicyclo-(3,3,1)-nonane, the latter compound was subjected to the action of acetyl, propionyl, and benzoyl chlorides in anhydrous benzene, with cooling. The 9-acetyl- (II, a), 9-propionyl- (II, b), and 9-benzoyl-3,9-oxazabicyclo-(3,3,1)-nonanes, (II, c), were reduced with lithium aluminum hydride to the corresponding amines.

When the compound 9-(β-chloropropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane(previously described by us [1])was reacted with morpholine and dimethylamine in anhydrous alcohol, with phenothiazine in anhydrous benzene, and with the sodium salt of quinosolone-4 in anhydrous alcohol, we obtained the corresponding β-substituted 9-propionyl-3,9-oxazabicyclo-(3,3,1)-nonanes (II, d; II, e; II, f; and II, g). It also was found that when 9-(β-chloropropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane was reacted with phenothiazine and quinosolone-4, we obtained 9-acryloyl-3,9-oxazabicyclo-(3,3,1)-nonane as a byproduct.



The formation of this compound is explained by the splitting out of hydrogen chloride from 9-(β-chloropropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane in alkaline medium.

When chloroacetyl chloride was reacted with 3,9-oxazabicyclo-(3,3,1)-nonane under the conditions described for β-chloropropionyl chloride [1] (aqueous alkaline medium), substitution of two chlorines occurred in the 3,9-oxazabicyclo-(3,3,1)-nonane, and 9-[3',9'-oxazabicyclo-(3',3',1')-nonano-9']-acetyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, k), was formed as a byproduct of the reaction.

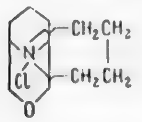


To free this compound of slight contamination by 9-chloroacetyl-3,9-oxazabicyclo-(3,3,1)-nonane that was formed in the reaction, the reaction product was treated with diethylamine in boiling anhydrous alcohol. If the reaction was carried out in anhydrous benzene, substitution took place only on the acyl chloride group and 9-chloroacetyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, a) was obtained. The latter on reaction with piperidine and morpholine in anhydrous alcohol yielded 9-(N-piperidinoacetyl)-(II, i) and 9-(N-morpholinoacetyl)-3,9-oxazabicyclo-(3,3,1)-nonane (II, j).

(II, d), (II, e), (II, i), (II, j), and (II, k) were reduced with lithium aluminum hydride to the corresponding amines (II, o), (II, p), (II, q), (II, r), and (II, s). We were not able to reduce compounds (II, f) and (II, g) in this manner. The desired amines were prepared in the following way.

3,9-Oxazabicyclo-(3,3,1)-nonane was reacted with carboethoxyacetyl chloride. The 9-carboethoxyacetyl-3,9-oxazabicyclo-(3,3,1)-nonane (III, a) that was obtained was reduced with lithium aluminum hydride to 9-(γ-hydroxypropyl)-3,9-oxazabicyclo-(3,3,1)-nonane (VI, a). When this last compound was reacted with phenothiazine and quinosolone-4, the corresponding 9-[γ-(N-phenothiazino)propyl]- (VII, a) and 9-[γ-(3'-quinosolone-4')-propyl]-3,9-oxazabicyclo-(3,3,1)-nonanes(VII, b) were obtained.

In a similar manner, starting with β-carboethoxypropionyl chloride and β-carbomethoxypropionyl chloride, we obtained 9-(β-carboethoxy)- (III, b) and 9-(β-carbomethoxy)-propionyl-3,9-oxazabicyclo-(3,3,1)-nonane (III, c), which upon reduction with lithium aluminum hydride yielded 9-(δ-hydroxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane (IV, b). By reacting the last-named compound with thionyl chloride, we obtained the hydrochloride of 9-(δ-chlorobutyl)-3,9-oxazabicyclo-(3,3,1)-nonane (VI, b). When we attempted to isolate the free base, we obtained a quaternary salt that apparently had the structure shown at the left.



(VI, b) reacted with phenothiazine to form 9-[δ-(N-phenothiazino)-butyl]-3,9-oxazabicyclo-(3,3,1)-nonane (VII, c) in 34% yield; it did not react with quinosolone-4. Obviously, in this case the conversion of the chloride (VI, b) to the quaternary salt went more rapidly than its reaction with quinosolone-4.

When (VI, b) was treated with alcoholates it formed ethers. We obtained 9-(δ-methoxybutyl)- (VII, d) and 9-(δ-ethoxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane (VII, e).

The first of these ethers was obtained in insignificant yield, but the second, apparently, as a result of the higher reaction temperature, was obtained in 64% yield.

When 9-(γ-hydroxypropyl)- and 9-(δ-hydroxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane were reacted with acetyl, propionyl, benzoyl, nicotinyl, and isonicotinyl chlorides, the corresponding esters, which are shown in the table, were obtained.

EXPERIMENTAL

9-Acetyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, a). To a solution of 3.7 g of 3,9-oxazabicyclo-(3,3,1)-nonane in 10 ml of anhydrous benzene cooled with ice was added dropwise, with stirring, a solution of 1.14 g of acetyl chloride in 10 ml of anhydrous benzene. The reaction mixture was stirred for 30 minutes with cooling and for 2.5 hours at room temperature. Then 35 ml of anhydrous ether was added, the hydrochloride of the starting 3,9-oxazabicyclo-(3,3,1)-nonane that had formed was filtered off, the filtrate was evaporated in vacuo, and the residue was distilled. The yield was 1.74 g (70%) of material with b. p. 106-109° (1 mm), which crystallized upon cooling. M. p. 74-75°.

Found %: C 63.89; H 8.96; N 8.08. $C_9H_{15}O_2N$. Calculated %: C 63.90; H 8.87; N 8.28.

9-Propionyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, b). By the method described above, 2 g (60%) of material with b. p. 113-114° (0.6 mm) was obtained from 4.61 g of 3,9-oxazabicyclo-(3,3,1)-nonane and 1.85 g of propionyl chloride.

Found %: C 65.10; H 9.38; N 7.57. $C_{10}H_{17}O_2N$. Calculated %: C 65.57; H 9.29; N 7.65.

9-Benzoyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, c). In a manner similar to that described above, 2.78 g (81%) of material with b. p. 162-163° (0.7 mm) and m. p. 78-80° was obtained from 3.75 g of 3,9-oxazabicyclo-(3,3,1)-nonane and 2.07 g of benzoyl chloride.

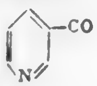
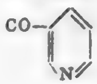
Found %: C 72.61; H 7.28; N 5.62. $C_{14}H_{17}O_2N$. Calculated %: C 72.72; H 7.35; N 6.06.

9-[β-(N-Morpholinopropionyl)]-3,9-oxazabicyclo-(3,3,1)-nonane (II, d). 3.03 g of technical 9-(β-chloropropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane [1], 2.42 g of morpholine, and 20 ml of anhydrous alcohol were heated at boiling for 5 hours. Then the alcohol was distilled off in vacuo and the residue was treated with an excess of 50% potassium carbonate solution and extracted with chloroform. The chloroform extract was dried with calcined sodium sulfate, the chloroform was distilled off, and the residue was distilled in vacuo. The yield was 2.69 g (72%) of material with b. p. 183-185° (0.2 mm), in the form of a colorless, caramel-like mass.

Found %: C 62.77; H 8.73; N 10.09. $C_{14}H_{24}O_3N_2$. Calculated %: C 62.68; H 8.95; N 10.44.

The hydrochloride was a white crystalline material with m. p. 228-230°.

(V)

n	R	Reaction time (in hours)	Reaction Temp.	Yield (in %)	B.p. of base (pressure in mm)	M.p. of hydrochloride	% C found	% C calc.	% H found	% H calc.	% N found	% N calc.	% Cl found	% Cl calc.
3	$COCH_3$	4	Boiling	67	—	200—202°					5.31	5.25	13.47	13.42
3	COC_2H_5	4	Boiling	58	—	170—172					5.04	4.78	12.79	12.72
3	COC_6H_5	4	Boiling	80	—	189—191					4.30	4.34	10.90	11.00
											Base			
3 *		3	60—70°	59	183.5° (0.9)	179—181	66.20	66.30	7.58	7.50	9.65	9.90	—	—
										Dihydrochloride				
											7.71	7.20	1955	19.31
											Base			
3 **		1	45—50	72	183 (1)	150—152	66.20	66.24	7.58	7.74	9.65	9.52	—	—
										Dihydrochloride				
											7.34	7.33	19.16	18.66
4	$COCH_3$	4	Boiling	95	—	201—202					5.04	5.08	12.79	13.05
4	COC_2H_5	4	Boiling	~100	—	194—196					4.80	4.78	12.17	12.17
4	COC_6H_5	4	Boiling	87	—	194—195.5					4.12	4.22	10.45	10.52
											Base			
4 *		2	60	67	200—201 (0.8)	137—139	67.10	67.11	7.89	8.01	9.21	9.21	—	—
										Dihydrochloride				
											7.42	7.23	18.85	18.48
											Base			
4 **		2	60	60	184 (0.9)	152—154	67.10	66.84	7.89	7.68	9.21	9.21	—	—
										Dihydrochloride				
											7.08	6.97	17.97	17.87

* Isolated as the dihydrochlorides.

** Isolated as the dihydrochlorides, which crystallize with 1 molecule of H_2O.

Found %: N 9.32; Cl 11.28. $C_{14}H_{25}O_3N_2Cl$. Calculated %: N 9.19; Cl 11.65.

9-(β-Dimethylaminopropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane (II, e). 2.61 g of technical 9-(β-chloropropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane and 16 ml of a 19% alcohol solution of diethylamine were heated at boiling for 5 hours. After suitable treatment, 2.03 g (75%) of material was obtained which boiled at 140° (0.8 mm) and crystallized on cooling. M. p. 68-70°.

Found %: C 63.80; H 9.67; N 12.24. $C_{12}H_{22}O_2N_2$. Calculated %: C 63.71; H 9.73; N 12.38.

The hydrochloride was a white crystalline material with m. p. 201-203°.

Found %: N 10.79; Cl 13.37. $C_{12}H_{23}O_2N_2Cl$. Calculated %: N 10.66; Cl 13.52.

9-[β-(N-Phenothiazino)-propionyl]-3,9-oxazabicyclo-(3,3,1)-nonane (II, f). 3.32 g of 9-(β-chloropropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane, 2.02 g of phenothiazine, and 1.01 g of pulverized sodium hydroxide were heated at boiling in 70 ml of anhydrous benzene in a Dean-Stark apparatus. The reaction was carried on until water ceased to distill off. About 0.2 ml (theoretical 0.2 ml) distilled off in 5-6 hours. After this, the benzene was distilled off from the reaction mass in vacuo and the residue was treated with an excess of 50% potassium carbonate and extracted with ether. The ether extract was dried with anhydrous sodium sulfate and the ether was distilled off. The residue was distilled in vacuo at 0.5 mm and two fractions were obtained: 1st, 101-103°, 1.02 g; and 2nd, 260°, 2.17 g (56%). The first fraction was a colorless transparent liquid which gave a reaction for a double bond and was 9-acryloyl-3,9-oxazabicyclo-(3,3,1)-nonane.

Found %: C 65.94; H 8.50; N 7.59. $C_{10}H_{15}O_2N$. Calculated %: C 66.29; H 8.28; N 7.73.

The second fraction was a light-yellow, caramel-like mass, which was 9-[β-(N-phenothiazine) propionyl]-(3,3,1)-nonane.

Found %: C 69.53; H 6.65; N 7.14. $C_{22}H_{24}O_2N_2S$. Calculated %: C 69.47; H 6.31; N 7.36.

9-[β-(3'-Quinosolone-4') propionyl]-3,9-oxazabicyclo-(3,3,1)-nonane (II, g). 0.51 g of metallic sodium was dissolved in 15 ml of anhydrous ethyl alcohol. To the warm solution was added 3.24 g of quinosolone-4 and the reaction mixture was shaken until the material completely dissolved. To the brown solution that formed was added 4.83 g of 9-(β-chloropropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane in 15 ml of anhydrous alcohol and the reaction mixture was heated at boiling until the alkaline reaction to phenolphthalein disappeared (10-12 hours). At the end of the reaction, the solution was evaporated in vacuo, 3-5 ml of water was added to dissolve the sodium chloride that had formed, and then the mixture was treated with excess 50% potassium carbonate solution and extracted with ether. The ether extract was dried with anhydrous sodium sulfate, the ether was distilled off, and the residue was distilled in vacuo. 0.6 g of a material with b. p. 101-103° (0.5 mm) [9-acryloyl-3,9-oxazabicyclo-(3,3,1)-nonane] and 2.5 g of a caramel-like mass with b. p. 230-240° (0.7 mm) were obtained. The material with b. p. 230-240° was dissolved in 10 ml of anhydrous ether and allowed to stand overnight. The white crystals that separated out were filtered off. 2 g (27%) of a material with m. p. 138-139° was obtained, which was 9-[β-(3'-quinosolono-4') propionyl]-3,9-oxazabicyclo-(3,3,1)-nonane. The material was readily soluble in alcohol and chloroform, but difficultly soluble in water.

Found %: C 65.77; H 6.70; N 13.01. $C_{18}H_{21}O_3N_3$. Calculated %: C 66.05; H 6.42; N 12.84.

9-Chloroacetyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, h). 4.22 g of 3,9-oxazabicyclo-(3,3,1)-nonane was dissolved in 14 ml of dry benzene and while the reaction mixture was stirred and cooled with ice, a solution of 1.9 g of chloroacetyl chloride in 10 ml of dry benzene was added dropwise. When this addition was completed, the reaction mixture was stirred for 30 minutes in ice and for 2.5 hours at room temperature, after which 35 ml of anhydrous ether was added. The precipitate of the hydrochloride of the starting 3,9-oxazabicyclo-(3,3,1)-nonane that had separated out was filtered off and washed with ether. The weight of the precipitate was 2.3 g. The ether-benzene mother liquors were evaporated and the residue was distilled in vacuo. 2.69 g (78%) of a colorless, caramel-like material was obtained with b. p. 124-126° (0.5 mm), m. p. 77-79°.

Found %: N 6.81; Cl 17.47. $C_9H_{14}O_2NCl$. Calculated %: N 6.88; Cl 17.44.

9-(N-Piperidinoacetyl)-3,9-oxazabicyclo-(3,3,1)-nonane (II, i). 1.5 g of 9-chloroacetyl-3,9-oxazabicyclo-(3,3,1)-nonane, 1.3 g of piperidine, and 20 ml of anhydrous alcohol were heated at boiling for 5 hours. The further treatment was as described above. The material was extracted with ether. 1.55 g (83%) of a

colorless, caramel-like mass was obtained with b. p. 157-159° (0.55 mm), m. p. 97-99°.

Found %: C 67.00; H 9.41; N 11.05. $C_{14}H_{24}O_2N_2$. Calculated %: C 66.66; H 9.52; N 11.11.

The hydrochloride was a white crystalline material with m. p. 256° (decomp.).

Found %: N 9.43; Cl 12.24. $C_{14}H_{24}O_2N_2 \cdot HCl$. Calculated %: N 9.70; Cl 12.34.

9-(N-Morpholinoacetyl)-3,9-oxazabicyclo-(3,3,1)-nonane (II, j). From 2.8 g of 9-chloroacetyl-3,9-oxazabicyclo-(3,3,1)-nonane and 2.93 g of morpholine there was obtained, by the above-described method, 3.11 g (90%) of a colorless, caramel-like mass with b. p. 148-150° (0.4 mm), m. p. 100-102°.

Found %: C 61.62; H 8.84; N 10.95. $C_{13}H_{22}O_3N_2$. Calculated %: C 61.45; H 8.66; N 11.02.

The hydrochloride was a white crystalline material with m. p. 264-266° (decomp.).

Found %: N 9.44; Cl 12.21. $C_3H_{23}O_3N_2Cl$. Calculated %: N 9.67; Cl 12.22.

9-[3',9'-Oxazabicyclo-(3',3',1')-nonano-9']acetyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, k). 6 g of the hydrochloride of 3,9-oxazabicyclo(3,3,1)-nonane was dissolved in 12 ml of water and, while the mixture was stirred and kept at a temperature of not more than 5°, a solution of 1.46 g of sodium hydroxide in 4.8 ml of water was added. Then, at the same temperature, 4.54 g of chloroacetyl chloride and a solution of 1.6 g of sodium hydroxide in 5.2 ml of water were added simultaneously, drop by drop. When the introduction of the acid chloride had been completed, stirring was continued for 30 minutes more, with cooling, and then the cooling was discontinued and the mixture was stirred until the temperature rose to 15-16°. The reaction mixture was made alkaline with excess 50% potassium carbonate solution and extracted with ether. The ether extract was dried with anhydrous sodium sulfate and the ether was distilled off. The residue, in the amount of 6 g, was dissolved in 20 ml of anhydrous alcohol, 7.5 g of diethylamine was added, and the reaction mixture was heated for 5 hours at boiling. When the reaction had ended, the alcohol and excess diethylamine were distilled off in vacuo, and the residue was treated with an excess of 50% potassium carbonate solution and extracted with chloroform. The chloroform extract was dried with calcined sodium sulfate and the chloroform was distilled off. The residue, which formed oily crystals, was treated with 10 ml of anhydrous ether and filtered. 3 g (43%) of a white crystalline material was obtained with m. p. 140-142°.

Found %: C 65.16; H 8.80; N 9.24. $C_{16}H_{26}O_3N_2$. Calculated %: C 65.30; H 8.84; N 9.52.

The hydrochloride was a white crystalline material with m. p. 263-264° (decomp.).

Found %: N 8.13; Cl 10.64. $C_{16}H_{27}O_3N_2Cl$. Calculated %: N 8.47; Cl 10.43.

9-Ethyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, l). 1.73 g of 9-acetyl-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 1.16 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 1.28 g (81%) of a material with b. p. 67-67.5° (3 mm), was obtained.

Found %: C 69.18; H 10.66; N 9.11. $C_9H_{17}ON$. Calculated %: C 69.67; H 10.96; N 9.03.

The methiodide, which formed white crystals with m. p. 290-291°, crystallized with 1 molecule of water.

Found %: N 4.25; I 40.37. $C_{10}H_{22}O_2NI$. Calculated %: N 4.44; I 40.31.

9-Propyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, m). 1.75 g of 9-propionyl-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 0.72 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 1.03 g (64%) of a material with b. p. 55-56° (0.8 mm), was obtained.

The methiodide was a white crystalline material with m. p. 278-280°.

Found %: N 4.36; I 40.76. $C_{11}H_{22}ONI$. Calculated %: N 4.50; I 40.83.

9-Benzyl-3,9-oxazabicyclo-(3,3,1)-nonane (II, n). 2.97 g of 9-benzoyl-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 1.46 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 2.6 g (93%) of a material with b. p. 119-121° (0.7 mm), m. p. 38-40°, was obtained.

Found %: C 77.22; H 8.79; N 6.33. $C_{14}H_{19}ON$. Calculated %: C 77.41; H 8.75; N 6.45.

The methiodide was a white crystalline material with m. p. 225-227°.

Found %: N 4.06; I 35.27. $C_{15}H_{22}ONI$. Calculated %: N 3.90; I 35.37.

9-[γ-(N-Morpholino)propyl]-3,9-oxazabicyclo-(3,3,1)-nonane (II, o). 1.86 g of 9-[β-(N-morpholino)-propionyl]-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 0.5 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 1.28 g (72%) of a material with b. p. 140-142° (0.6 mm) was obtained.

Found %: C 65.98; H 10.07; N 11.05. $C_{14}H_{26}O_2N_2$. Calculated %: C 66.14; H 10.23; N 11.02.

The monomethiodide was a white crystalline material with m. p. 156.5-158.5°. It was produced when 9-[γ-(N-morpholino)propyl]-3,9-oxazabicyclo-(3,3,1)-nonane stood for a long time in the cold with an excess of methyl iodide in anhydrous acetone. It was soluble in alcohol and acetone.

Found %: N 6.98; I 32.10. $C_{15}H_{29}O_2N_2I$. Calculated %: N 7.07; I 32.07.

The dimethiodide was a white crystalline material with m. p. 227-229°. It was produced along with the monomethiodide when 9-[γ-(N-morpholino)propyl]-3,9-oxazabicyclo-(3,3,1)-nonane was boiled for a long time with an excess of methyl iodide in acetone; it was not soluble in alcohol and acetone.

Found %: N 5.10; I 47.57. $C_{16}H_{32}O_2N_2I_2$. Calculated %: N 5.20; I 47.21.

9-(γ-Dimethylaminopropyl)-3,9-oxazabicyclo-(3,3,1)-nonane (II, p). 2.11 g of 9-(β-dimethylamino-propionyl)-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 0.52 g of lithium aluminum hydride in ether solution for 20 hours. 1.23 g (62%) of a material with b. p. 98-100° (0.6 mm) was obtained.

Found %: C 67.71; H 11.19; N 13.23. $C_{12}H_{24}ON_2$. Calculated %: C 67.92; H 11.32; N 13.20.

The dimethiodide was a white crystalline material with m. p. 244-245°. It was formed when 9-(γ-dimethylaminopropyl)-3,9-oxazabicyclo-(3,3,1)-nonane was boiled for a long time with an excess of methyl iodide in acetone; it was insoluble in acetone.

Found %: N 5.38; I 50.68. $C_{14}H_{30}ON_2I_2$. Calculated %: N 5.64; I 51.20.

9-[β-(N-Piperidino)ethyl]-3,9-oxazabicyclo-(3,3,1)-nonane (II, r). 2.57 g of 9-(N-piperidinoacetyl)-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 0.83 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 1.93 g (79%) of a material with b. p. 108° (0.35 mm) was obtained.

Found %: C 70.30; H 10.76; N 11.78. $C_{14}H_{26}ON_2$. Calculated %: C 70.58; H 10.92; N 11.76.

The dihydrochloride was a white crystalline material with m. p. 218-220°; it crystallized with one molecule of water.

Found %: N 8.22; Cl 21.48. $C_{14}H_{30}O_2N_2Cl_2$. Calculated %: N 8.51; Cl 21.58.

9-[β-(N-Morpholino)ethyl]-3,9-oxazabicyclo-(3,3,1)-nonane (II, s). 2.85 g of 9-(N-morpholinoacetyl)-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 0.87 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 1.88 g (70%) of a material with b. p. 118-120° (0.3 mm) was obtained.

Found %: C 64.45; H 9.90; N 11.62. $C_{13}H_{24}O_2N_2$. Calculated %: C 65.00; H 10.00; N 11.66.

The dihydrochloride was a white crystalline material with m. p. 220-222° (decomp.).

Found %: N 8.81; Cl 22.16. $C_{13}H_{28}O_2N_2Cl_2$. Calculated %: N 8.94; Cl 22.68.

9-{β-[3',9'-Oxazabicyclo-(3',3',1')-nonano-9']ethyl}-3,9-oxazabicyclo-(3,3,1)-nonane (II, t). 2.3 g of 9-[3',9'-oxazabicyclo-(3',3',1')-nonano-9']-acetyl-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 0.59 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 1.85 g (84%) of a crystalline material with m. p. 113-115° was obtained.

Found %: C 68.41; H 9.97; N 10.16. $C_{16}H_{28}O_2N_2$. Calculated %: C 68.57; H 10.00; N 10.00.

The dihydrochloride was a white crystalline material with m. p. 272-274°.

Found %: N 7.64; Cl 20.08. $C_{16}H_{30}O_2N_2Cl_2$. Calculated %: N 7.93; Cl 20.11.

9-Carboethoxyacetyl-3,9-oxazabicyclo-(3,3,1)-nonane (III, a). To a solution of 5.57 g of 3,9-oxazabicyclo-(3,3,1)-nonane in 20 ml of anhydrous benzene cooled with ice, was added dropwise, with stirring, a solution of 3.3 g of carboethoxyacetyl chloride in 100 ml of anhydrous benzene. The reaction mixture was stirred for 30 minutes with cooling, and then for 2.5 hours at room temperature. 35 ml of anhydrous ether was added, the precipitate of the hydrochloride of the starting 3,9-oxazabicyclo-(3,3,1)-nonane (3.25 g) that was formed was filtered off, the filtrate was evaporated, and the residue was distilled. 4.1 g (77% calculated on the acid chloride) of a material with b. p. 157-159° (0.7 mm) was obtained.

Found %: C 59.64; H 8.02; N 5.70. $C_{12}H_{19}O_4N$. Calculated %: C 59.75; H 7.88; N 5.80.

9-(β-Carboethoxypropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane (III, b). From 5.18 g of 3,9-oxazabicyclo-(3,3,1)-nonane and 3.34 g of β-carboethoxypropionyl chloride, 2.85 g (55.0 %) of a caramel-like colorless mass was obtained by the method described above, with b. p. 151-152° (0.5 mm).

Found %: N 5.59, 5.69. $C_{13}H_{21}O_4N$. Calculated %: N 5.49.

9-(β-Carbomethoxypropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane (III, c). By a method similar to that described above, 4.28 g of 3,9-oxazabicyclo-(3,3,1)-nonane and 2.53 g of β-carbomethoxypropionyl chloride yielded 3.15 g (77 %) of 9-(β-carbomethoxypropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane, a white crystalline material with m. p. 63-65° and b. p. 171-172° (1 mm).

Found %: C 59.40; H 7.97; N 5.70. $C_{12}H_{19}O_4N$. Calculated %: C 59.75; H 7.88; N 5.80.

9-(γ-Hydroxypropyl)-3,9-oxazabicyclo-(3,3,1)-nonane (IV, a). 2.85 g of 9-carboethoxyacetyl-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 1.34 g of lithium aluminum hydride in ether-benzene solution for 20 hours. 1.43 g (65 %) of a material with b. p. 107-109° (0.5 mm) was obtained.

Found %: C 65.03; H 10.24; N 7.51. $C_{10}H_{19}O_2N$. Calculated %: C 64.86; H 10.27; N 7.56.

The hydrochloride was a white crystalline material with m. p. 149-151°, which crystallized with 1 molecule of water.

Found %: N 5.91; Cl 14.79. $C_{10}H_{22}O_3NCl$. Calculated %: N 5.84; Cl 14.82.

9-(δ-Hydroxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane (IV, b). a) 2 g of 9-(β-carboethoxypropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 1 g of lithium aluminum hydride in ether-benzene medium. 1.1 g (70%) of a colorless mobile liquid with b. p. 135-137° (1 mm) was obtained.

Found %: C 66.12; H 10.79; N 7.03. $C_{11}H_{21}O_2N$. Calculated %: C 66.33; H 10.55; N 7.03.

The hydrochloride was a white crystalline material with m. p. 142-144°.

Found %: N 5.91; Cl 15.04. $C_{11}H_{22}O_2NCl$. Calculated %: N 5.94; Cl 15.07.

b) 3.15 g of 9-(β-carbomethoxypropionyl)-3,9-oxazabicyclo-(3,3,1)-nonane was reduced with 1.5 g of lithium aluminum hydride in a mixture of ether and dioxane. 2.2 g (84%) of a colorless, very mobile liquid with b. p. 135-137° (1 mm) was obtained. The melting point of the hydrochloride was 142-144°. A mixed melting point test of the hydrochloride of this compound with the hydrochloride of 9-(δ-hydroxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane obtained by method "a" gave no depression.

Hydrochloride of 9-(γ-acetoxypropyl)-3,9-oxazabicyclo-(3,3,1)-nonane (V).* To a solution of 1.85 g of 9-(γ-hydroxypropyl)-3,9-oxazabicyclo-(3,3,1)-nonane in 5 ml of anhydrous benzene was added, through a condenser, a solution of 1.57 g of acetyl chloride in 10 ml of anhydrous benzene. The reaction mixture warmed up and a precipitate separated out. The mixture was heated at boiling for 4 hours. Then 15 ml of anhydrous ether was added to the cooled reaction mixture and the precipitate was filtered off and recrystallized from anhydrous alcohol with the addition of a small amount of anhydrous ether for crystallization. 1.78 g (67%) of a white crystalline material was obtained with m. p. 200-202°.

* n = 3, R = $COCH_3$, see table.

Found %: N 5.25; Cl 13.42. $C_{12}H_{22}O_3NCl$. Calculated %: N 5.31; Cl 13.47.

9-(γ-Nicotinyloxypropyl)-3,9-oxazabicyclo-(3,3,1)-nonane (V).* To a solution of 1.5 g of 9-(γ-hydroxypropyl)-3,9-oxazabicyclo-(3,3,1)-nonane in 5 ml of anhydrous benzene was added, through a condenser, a solution of 2.3 g of nicotinyl chloride in 10 ml of anhydrous benzene. The mixture became very warm and a precipitate separated out. The mixture was heated for 3 hours at 60-70° on a water bath, cooled, 10 ml of anhydrous ether was added, and the precipitate was filtered off, dissolved in a small amount of water, made alkaline with an excess of 50% potassium carbonate solution, and extracted with ether. The ether extract was dried with calcined sodium sulfate and the ether was distilled off. The residue was distilled. 1.4 g (60%) of a colorless material was obtained with b. p. 183.5° (0.9 mm).

Found %: C 66.30; H 7.50; N 9.90. $C_{16}H_{22}O_3N_2$. Calculated %: C 66.20; H 7.58; N 9.65.

The dihydrochloride formed white hygroscopic crystals with m. p. 179-181°.

Found %: N 7.20; Cl 19.31. $C_{16}H_{24}O_3N_2Cl_2$. Calculated %: N 7.71; Cl 19.55.

9-(γ-Chloropropyl)-3,9-oxazabicyclo-(3,3,1)-nonane (VI, a). 1.33 g of the hydrochloride of 9-(γ-hydroxypropyl)-3,9-oxazabicyclo-(3,3,1)-nonane, 5.5 ml of dry chloroform, and 5.5 ml of thionyl chloride were heated at 45° for 1 hour. The chloroform and excess thionyl chloride were distilled off in vacuo. The residue was triturated with anhydrous ether, filtered, and recrystallized from anhydrous alcohol. 1 g (75%) of a white crystalline material was obtained with m. p. 217-219° (decomp.).

Found %: C 49.68; H 7.70; N 5.74; Cl 29.63. $C_{10}H_{19}ONCl_2$. Calculated %: C 50.00; H 7.91; N 5.83; Cl 29.58.

When the hydrochloride of 9-(γ-chloropropyl)-3,9-oxazabicyclo-(3,3,1)-nonane was treated with an excess of 50% potassium carbonate solution, the base was obtained in the form of a colorless, very mobile liquid with b. p. 98° (0.8 mm).

Found %: N 6.53, 6.73. $C_{10}H_{18}ONCl$. Calculated %: N 6.87.

Hydrochloride of 9-(δ-chlorobutyl)-3,9-oxazabicyclo-(3,3,1)-nonane (VI, b). From 2.95 g of the hydrochloride of 9-(δ-hydroxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane, 12 ml of dry chloroform, and 12 ml of thionyl chloride there was obtained by the above-described method 2.55 g (80%) of a white crystalline material with m. p. 173-175°.

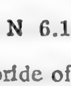
Found %: C 52.10; H 8.51; N 5.63; Cl 27.70. $C_{11}H_{21}ONCl_2$. Calculated %: C 51.96; H 8.26; N 5.51; Cl 27.95.

1 g of the hydrochloride of 9-(δ-chlorobutyl)-3,9-oxazabicyclo-(3,3,1)-nonane was dissolved in 2 ml of water, made alkaline with an excess of 50% potassium carbonate solution, and extracted with ether. When the ether extract stood, a colorless oily material separated, which upon repeated trituration with anhydrous ether was converted to very hygroscopic white crystals. It was not possible to determine the melting point of these crystals because of their hygroscopy.

Found %: N 6.10; Cl 15.91. $C_{11}H_{20}ONCl$. Calculated %: N 6.43; Cl 16.32.

Hydrochloride of 9-[γ-(N-phenothiazino)propyl]-3,9-oxazabicyclo-(3,3,1)-nonane (VII, a). 3.65 g of the hydrochloride of 9-(γ-chloropropyl)-3,9-oxazabicyclo-(3,3,1)-nonane, 2.02 g of phenothiazine, 1.61 g of pulverized sodium hydroxide, and 70 ml of anhydrous benzene were heated in a Dean-Stark apparatus as described above. When the reaction had ended, the benzene was distilled off in vacuo and the residue was treated with 5% hydrochloric acid. The acid aqueous solution was made alkaline with an excess of 40% sodium hydroxide solution and extracted with ether. After the ether extract was dried, the solvent was distilled off, and the residue was distilled in vacuo, 0.99 g of a material with b. p. 98° (0.8 mm) was obtained, which was the starting 9-(γ-chloropropyl)-3,9-oxazabicyclo-(3,3,1)-nonane.

---

* n = 3, R = CO , see table.

The mass that did not dissolve in the hydrochloric acid was washed 2-3 times with small portions of ether, then dissolved in dry acetone. After short standing, a precipitate separated out. It was left to crystallize for 8 hours at − 5°. Then it was filtered off and 1.7 g (41%) of (VII, a) was obtained with m. p. 234-236° (from alcohol).

Found %: N 6.84; Cl 8.82; S 7.90. $C_{22}H_{27}ON_2SCl$. Calculated %: N 6.95; Cl 8.81; S 7.95.

9-[γ-(3'-Quinosolono-4')propyl]-3,9-oxazabicyclo-(3,3,1)-nonane (VII, b). To a solution of the sodium salt of quinosolone-4, which was prepared from 0.77 g of metallic sodium, 2.43 g of quinosolone-4, and 20 ml of alcohol, was added 4 g of the hydrochloride of 9-(γ-chloropropyl)-3,9-oxazabicyclo-(3,3,1)-nonane, and the mixture was heated at boiling for 15-17 hours. When the reaction had ended, the sodium chloride that had precipitated was filtered off and the filtrate was evaporated in vacuo. The residue was treated with an excess of 50% potassium carbonate solution and extracted with ether. After the extract had been dried, the solvent distilled off, and the reaction mass distilled in vacuo; 0.4 g of a material with b. p. 98° (0.8 mm) was obtained, which was the starting chloride, and also 2.7 g (52%) of a caramel-like mass with b. p. 215° (0.8 mm).

Found %: C 68.98; H 7.55; N 13.14. $C_{18}H_{23}O_2N_3$. Calculated %: C 69.00; H 7.34; N 13.41.

The dihydrochloride was a white crystalline material with m. p. 208-210°, which crystallized with one molecule of water.

Found %: N 10.10; Cl 17.78. $C_{18}H_{27}O_3N_3Cl_2$. Calculated %: N 10.39; Cl 17.57.

Hydrochloride of 9-[δ-(N-phenothiazino)butyl]-3,9-oxazabicyclo-(3,3,1)-nonane (VII, c). A mixture of 4.55 g of the hydrochloride of 9-(δ-chlorobutyl)-3,9-oxazabicyclo-(3,3,1)-nonane, 2.37 g of phenothiazine, 1.97 g of sodium hydroxide, and 70 ml of benzene was heated in a Dean-Stark apparatus as described above. When the reaction had ended, the sodium chloride that had formed was filtered off, and the filtrate was evaporated in vacuo. The residue was dissolved in 5% hydrochloric acid and extracted with ether to remove the unreacted phenothiazine. The acid aqueous solution was evaporated in vacuo and the residue was dissolved in acetone. When ether was added, a precipitate separated out. It was filtered off and washed with a small amount of acetone. 1.7 g (34%) of a material with m. p. 194-196° was obtained.

Found %: N 6.67; Cl 8.52; S 7.71. $C_{23}H_{29}ON_2SCl$. Calculated %: N 6.72; Cl 8.52; S 7.68.

9-(δ-Methoxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane (VII, d). 0.27 g of metallic sodium was dissolved in 10 ml of anhydrous methyl alcohol. When the solution obtained was added to a hot solution of 1.5 g of the hydrochloride of 9-(δ-chlorobutyl)-3,9-oxazabicyclo-(3,3,1)-nonane in 10 ml of anhydrous methyl alcohol, a precipitate separated out. The reaction mixture was boiled for 15-17 hours. Then the precipitate was filtered off and the filtrate was evaporated, treated with an excess of 50% potassium carbonate solution, and extracted with ether. The main bulk of the oily layer that separated did not go into the ether (quaternary compound). The ether solution was dried with calcined sodium sulfate and the ether was distilled off. The residue was again dissolved in a small amount of ether and acidified with an alcoholic solution of hydrogen chloride. 0.15 g of the crystalline hydrochloride was obtained with m. p. 163-165°.

Found %: N 5.59; Cl 14.41. $C_{12}H_{24}O_2NCl$. Calculated %: N 5.61; Cl 14.23.

4-(δ-Ethoxybutyl)-3,9-oxazabicyclo-(3,3,1)-nonane (VII, e). By the method described above, there was obtained from 1.5 g of the hydrochloride of 9-(δ-chlorobutyl)-3,9-oxazabicyclo-(3,3,1)-nonane, 0.27 g of metallic sodium, and 20 ml of anhydrous alcohol, a yield of 1 g (64%) of a crystalline precipitate with m. p. 176-177° (from alcohol).

Found %: N 5.35; Cl 13.36. $C_{13}H_{26}O_2NCl$. Calculated %: N 5.31; Cl 13.47.

SUMMARY

For the purpose of pharmacological investigation, N-acyl and N-alkyl derivatives of 3,9-oxazabicyclo-(3,3,1)-nonane have been prepared, including compounds containing in the acyl and alkyl groups such pharmacologically active systems as phenothiazine, quinosolone, and morpholine, and other ethers and esters of 9-(γ-hydroxypropyl)- and 9-(δ-hydroxybutyl)- 3,9-oxazabicyclo-(3,3,1)-nonanes.

LITERATURE CITED

[1] E.S. Nikit-skaya, V. S. Usovskaya, and M. V. Rubtsov, Zhur. Obshchei Khim. 29, 124 (1959).*

* Original Russian pagination. See C. B. translation.

INVESTIGATIONS IN THE FIELD OF p-QUINONES

XXIX. AZO COUPLING OF 2,5-BIS-(DIMETHYLAMINO)-1,4-BENZOQUINONE AND 2-DIMETHYLAMINO-1,4-NAPHTHOQUINONE

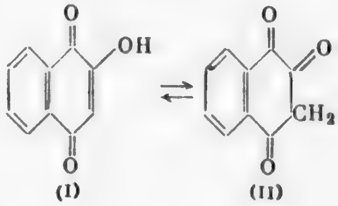
A. N. Grinev, N. K. Venevtseva, and A. P. Terent'ev

Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 183-185, January, 1960

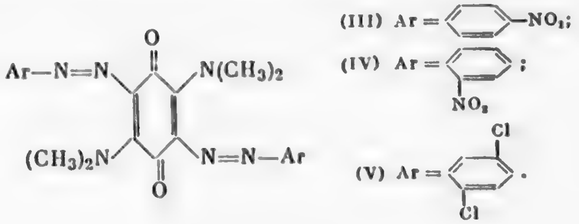
Original article submitted January 5, 1959

When diazonium salts react with 2-hydroxy-1,4-naphthoquinone (I), either products of azo coupling or aryl-substituted quinones are formed, depending on the reaction conditions [1, 2].* A number of azo compounds of 2-hydroxy-1,4-naphthoquinone have been described in [7]. In the case of 2-hydroxy-1,4-naphthoquinone, it can be assumed that it reacts in one of its tautomeric forms (II) and the reaction proceeds in a manner similar to the azo coupling of compounds with an active methylene group.



(I) (II)

The purpose of our work was to study the azo coupling of quinones with other electron-donor substituents. As examples of such compounds we selected 2,5-bis(dimethylamino)-1,4-benzoquinone and 2-dimethylamino-1,4-naphthoquinone. When we carried out the azo coupling of 2,5-bis(dimethylamino)-1,4-benzoquinone with various diazonium salts, we obtained high yields of 2,5-bis(dimethylamino)-3,6-bis(p-nitrophenylazo)-1,4-benzoquinone (III), 2,5-bis(dimethylamino)-3,6-bis(o-nitrophenylazo)-1,4-benzoquinone (IV), and 2,5-bis-(dimethylamino)-3,6-bis(2',5'-dichlorophenylazo)-1,4-benzoquinone (V).



* The reaction of quinones with diazonium salts under conditions where the latter decompose is a well-known method of synthesizing aryl-substituted quinones [3-6].

Expt. No.	Starting materials						Azo compounds obtained	Yield (in %)	% C		% H	
	quinone (in moles)	dioxane (in ml)	diazo solution*			sodium acetate (in moles)			found	calc.	found	calc.
			Amine (in moles)	acid (in ml)	H_2O (in ml)							
1**	2,5-Bis(dimethylamino)-1,4-benzoquinone (0.01)	50	p-Nitroaniline (0.026)	Conc. HCl (6)	88	0.04	2,5-Bis(dimethylamino)-3,6-bis(p-nitrophenylazo)-1,4-benzoquinone (III)	81.3	53.56, 53.49	53.66	4.13, 4.00	4.09
2		50	o-Nitroaniline (0.026)	Conc. H_2SO_4 (6)	15	0.24	2,5-Bis(dimethylamino)-3,6-bis(o-nitrophenylazo)-1,4-benzoquinone (IV)	38.6	53.20, 53.27	53.66	4.14, 4.17	4.09
3		50	2,5-Dichloroaniline (0.026)	Conc. H_2SO_4 (0.4)	26	0.085	2,5-Bis(dimethylamino)-3,6-bis(2,5-dichlorophenylazo)-1,4-benzoquinone (V)	65.9	48.88, 48.91	49.09	3.23, 3.47	3.00
4	2-Dimethylamino-1,4-naphthoquinone*** (0.01)	25	p-Nitroaniline (0.013)	Conc. HCl (3)	44	—	2-Hydroxy-3-(p-nitrophenylazo)-1,4-naphthoquinone (VI)	88.6	59.67, 59.46	59.44	2.97, 2.92	2.81
5		20	o-Nitroaniline (0.013)	Conc.**** H_2SO_4 (3).	7.5	—	2-Hydroxy-3-(o-nitrophenylazo)-1,4-naphthoquinone (VII)	77.1	60.08, 60.22	59.44	3.21, 3.21	2.81

* Sodium nitrite in small excess in concentrated aqueous solution was used for the diazotization. Diazotization was carried out in the usual way.

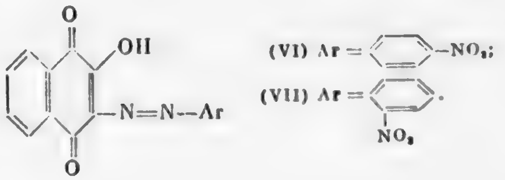
** See Expt. 1.

*** 2-Dimethylamino-1,4-naphthoquinone was prepared by the known method [10].

**** The diazo solution prepared was diluted with water to a volume of 50 ml..

The formation of these compounds affords a complete basis for assuming that the azo coupling reaction in the quinone series is the same as in the aromatic series - an electrophilic substitution reaction.

When diazonium salts reacted with 2-dimethylamino-1,4-naphthoquinone, we obtained, instead of the expected products of azo coupling of this compound, the following derivatives of 2-hydroxy-1,4-naphthoquinone: 2-hydroxy-3-(p-nitrophenylazo)-1,4-naphthoquinone (VI) and 2-hydroxy-3-(o-nitrophenylazo)-1,4-naphthoquinone (VII).



Probably under the reaction conditions, replacement of the dimethylamino group of 2-dimethylamino-1,4-naphthoquinone by the hydroxy group occurs readily, and then the azo coupling reaction takes place. To confirm this assumption we studied the effect of dilute acids on 2-dimethylamino-1,4-naphthoquinone. It turned out that under the reaction conditions for azo coupling (with the same concentrations of acid) the hydrolysis of the dimethylamino group took place very readily. There are indications in the literature of the ease of hydrolysis of the amino groups in quinones under other conditions [8, 9].

EXPERIMENTAL

1. 2,5-Bis(dimethylamino)-3,6-bis(p-nitrophenylazo)-1,4-benzoquinone (III). To a suspension of 1.9 g of 2,5-bis(dimethylamino)-1,4-benzoquinone* in 50 ml of dioxane were added, with cooling with ice, a solution of p-nitrophenyldiazonium chloride (prepared from 3.6 g of p-nitroaniline, 6 ml of concentrated hydrochloric acid, 88 ml of water, and a solution of 2 g of sodium nitrite in the minimum amount of water) and 5.4 g of sodium acetate. The reaction mixture was shaken for 2 hours at 0°, and then it was left overnight at a temperature of approximately 0°. The precipitate that formed was filtered off, washed with water and methyl alcohol, and dried in a vacuum desiccator over phosphoric anhydride. The yield of (III) was 4 g (81.3%).

Found %: C 53.56, 53.49; H 4.13, 4.00. $C_{22}H_{20}O_6N_8$. Calculated %: C 53.66; H 4.09.

The other azo compounds (IV-VII) were prepared under similar conditions. The results of the experiments that were carried out are given in the table. All of the azo compounds obtained (IV-VII) decomposed when heated above 170-180°, and also upon any prolonged heating and storage of their solutions. 2,5-Bis(dimethylamino)-3,6-bis(p-nitrophenylazo)-1,4-benzoquinone (III) was purified for analysis by very rapid recrystallization from chlorobenzene, the azo derivatives of 2-hydroxy-1,4-naphthoquinone (VI and VII) were purified by precipitation from solutions in acetic acid with petroleum ether, and the other azo compounds (IV and V) were freed of the starting quinones by washing on the filter with benzene, dichloroethane, and alcohol. The azo derivatives of 2,5-bis(dimethylamino)-1,4 benzoquinone (III-V) were orange in color, and those of 2-hydroxy-1,4-naphthoquinone were yellow.

SUMMARY

The azo coupling reaction of 2,5-bis(dimethylamino)-1,4-benzoquinone and 2-dimethylamino-1,4-naphthoquinone has been studied. It is assumed that this reaction proceeds by way of an electrophilic replacement mechanism.

* 2,5-Bis(dimethylamino)-1,4-benzoquinone was prepared by a known method [10].

LITERATURE CITED

[1] F. Kehrmann and M. Goldenberg, Ber. 30, 2125 (1897).

[2] O. Neunhoeffer and J. Weise, Ber. 71, 2703 (1938).

[3] German Patent No. 508,395; Frdl. 17, 557 (1930).

[4] D. Kwalnes, J. Am. Chem. Soc. 56, 2478 (1934).

[5] K. Schimmelschmidt, Lieb. Ann. 556, 184 (1950).

[6] G. Marini-Bettolo and C. Rossi, Gazz. 72, 208 (1942); Chem. Abstr. 37, 4386 (1943).

[7] L. Fieser, J. Am. Chem. Soc. 70, 3203 (1948).

[8] F. Kehrmann, Ber. 23, 907 (1890).

[9] F. Kehrmann, Ber. 23, 1264 (1890).

[10] R. Baltzly and E. Lorz, J. Am. Chem. Soc. 70, 861 (1948).

[11] R. Plimpton, J. Chem. Soc. 37, 642 (1880).

REACTIVITY OF UNSATURATED COMPOUNDS OF TIN AND LEAD

M. M. Koton, T. M. Kiseleva, and N. P. Zapevalova

Institute of High-Molecular Compounds of the Academy of Sciences of the USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 186-190, January, 1960

Original article submitted January 14, 1959

The unsaturated compounds of metals have been studied but little, and only recently have they begun to attract the attention of investigators for the purpose of determining the possibility of preparing polymers with new properties [1]. Among the unsaturated compounds of tin and lead, various allyl derivatives have been known [2, 3], and comparatively recently vinyl compounds of tin have been synthesized [4, 5]. It was of interest to investigate the reactivity of the unsaturated compounds of tin and lead in order to evaluate their capacity for polymerization and copolymerization.

M. M. Koton and T. M. Kiseleva [6] have shown that the allyl derivatives of tin form a series with respect to their reactivity (with HCl, I_2, and HCOOH): tetraallyl tin > diallyldiphenyl tin > allyltriphenyl tin. Thus, it has been experimentally shown that as the number of allyl radicals introduced into the molecule of the organotin compound increases, its reactivity also increases, and that the allyl radical is more active than the phenyl radical, i.e., allyl > phenyl.

Furthermore, under conditions of radical polymerization (in mass and in solution) the allyl compounds of tin do not yield polymers and exert an inhibiting effect on the polymerization of vinyl monomers (styrene, methy methacrylate, vinyl acetate), apparently as a result of trapping and binding the free radicals that form in the polymerization process [6]. The inhibitory effect increased with an increase in the number of allyl groups in the molecule of the organotin compound.

In amplifying these studies, we synthesized and investigated unsaturated compounds of tin and lead, namely: allyltrimethyl tin, vinyltrimethyl tin, vinyltriphenyl tin, divinyldiphenyl tin, tetravinyl tin, and allyltriphenyl lead.

Allyltriphenyl lead at room temperature reacts readily with HCl to yield propylene and triphenyl lead chloride, in contrast to allyltriphenyl tin, which under these conditions forms benzene, propylene, and stannic chloride.

$$(C_3H_5)Pb(C_6H_5)_3 + HCl \longrightarrow C_3H_6 + (C_6H_5)_3PbCl$$

Allyltriphenyl lead at room temperature reacts readily with iodine in xylene solution to form triphenyl lead iodide in quantitative yield.

$$(C_3H_5)Pb(C_6H_5)_3 + I_2 \longrightarrow C_3H_5I + (C_6H_5)_3PbI$$

If the reaction is carried out at boiling, then a more extensive reaction takes place with the formation of lead iodide.

Thus, as in the case of the allyl derivatives of tin [6], the allyl radical is more reactive in comparison with the phenyl radical [3].

Allyltriphenyl lead is thermally stable up to 160°, but at a higher temperature disproportionation is observed with the formation of tetraphenyl lead and the thermally unstable tetraallyl lead (not isolated in pure form), which breaks down into diallyl and metallic lead.

$$4(C_3H_5)Pb(C_6H_5)_3 \longrightarrow 3\ (C_6H_5)_4Pb + (C_3H_5)_4Pb$$
$$(C_3H_5)_4Pb \longrightarrow 2C_6H_{10} + Pb$$

Under these conditions allyltriphenyl tin, being thermally more stable, does not undergo any change upon heating up to 170°, which is in accordance with data [2] that indicate the instability of allyl derivatives of lead.

Allyltriphenyl lead does not polymerize under conditions of radical polymerization, in the presence of peroxides and azo compounds, but at 100-102° it breaks down to give metallic lead. Allyltriphenyl lead inhibits the polymerization of vinyl monomers (styrene and methyl methacrylate) even in the presence of initiators. As in the case of the allyl compounds of tin, the strongest inhibitory effect occurs with methyl methacrylate (Table 1).

TABLE 1

Polymerization of Styrene and Methyl Methacrylate with 5% Allyltriphenyl Lead and 0.1% Azodinitrile of Isobutyric Acid (100°, 2 hours).

Name of Monomer	Yield of Polymer (in %)
Pure styrene	34.7
Styrene + allyltriphenyl lead	30.2
Pure methyl methacrylate	97.5
Methyl methacrylate + allyltriphenyl lead	31.5

In a study of the reactivity of vinyl derivatives of tin of the general formula $R_2Sn(CH{=}CH_2)_2$ with iodine, hydrogen chloride, and hydrogen bromide, it was shown [4, 5] that the radicals investigated form a series with respect to the rate of splitting out of the atom of tin: phenyl > vinyl > methyl > ethyl > propyl > butyl.

We investigated the thermal stability of various vinyl derivatives of tin (Table 2) and showed that they can be arranged in a series with respect to their stability: vinyltrimethyl tin > vinyltriphenyl tin > divinyldiphenyl tin > tetravinyl tin.

With the accumulation of vinyl groups in the molecule of the organotin compound, the thermal stability decreases. These results are in good agreement with those previously obtained [6] for allyl derivatives of tin. Comparison of the thermal stability of the corresponding vinyl and allyl derivatives of tin (Table 2) shows that the vinyl compounds of tin are more stable, i.e., the allyl radical is split off from the tin atom more easily than the vinyl radical.

With regard to their reactivity, the radicals studied can be arranged in the following series: allyl > phenyl > > vinyl. The vinyl compounds of tin do not polymerize under conditions of radical polymerization in the presence of peroxides and azo compounds. Upon prolonged heating of tetravinyl tin and divinyldiphenyl tin in the presence of 2% azodinitrile of isobutyric acid in an atmosphere of nitrogen, 1-3% of insoluble, infusible materials are formed, which do not undergo change on heating to 300-400°, and apparently are polymeric compounds of tin.

The vinyl compounds of tin exert an inhibitory effect on the polymerization of vinyl monomers (styrene and methyl methacrylate). Comparison of the inhibiting effect of the allyl and vinyl compounds of tin on the polymerization of methyl methacrylate (Fig. 1) and styrene (Fig. 2) shows that the allyl compounds of tin are more effective inhibitors of the polymerization than are the corresponding vinyl compounds.

The compounds studied can be arranged in a series with respect to their inhibitory effect on the polymerization of the vinyl monomers: tetraallyl tin >> tetravinyl tin > allyltrimethyl tin > diallyldiphenyl tin > allyltriphenyl tin > vinyltriphenyl tin > vinyltrimethyl tin.

TABLE 2

Thermal Stability of Unsaturated Compounds of Tin and Lead

Name of unsaturated compound	150°	170-180°	200°	250°	300°
Tetraallyl tin	Stable	Decomp.	–	–	–
Tetravinyl tin	Stable	Part. decomp.	Part. decomp.	Decomp.	–
Allyltriphenyl lead	Stable	Decomp.	–	–	–
Allyltriphenyl tin	Stable	Stable	–	–	–
Vinyltriphenyl tin	Stable	Stable	Part. decomp.	Decomp.	–
Diallyldiphenyl tin	Stable	Part. decomp.	–	–	–
Divinyldiphenyl tin	Stable	Stable	Part. decomp.	Decomp.	–
Vinyltrimethyl tin	Stable	Stable	Stable	Part. decomp.	Decomp.

Note. Decomp. = decomposes; part. decomp. = partially decomposes.

Comparison of the various unsaturated compounds of tin with respect to thermal stability and inhibiting effect on the radical polymerization of vinyl monomers shows that the most effective inhibitors are the least thermostable unsaturated compounds of tin (tetraallyl tin).

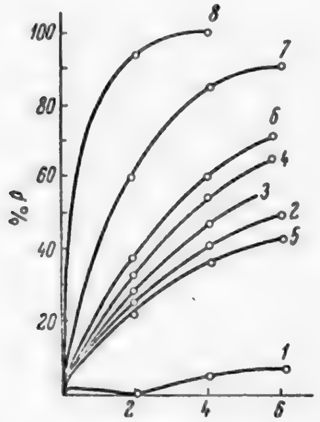


Fig. 1. Polymerization of methyl methacrylate at 120° in the presence of 5 wt.% of unsaturated compounds of tin: 1) tetraallyl tin; 2) allyltrimethyl tin; 3) diallyldiphenyl tin; 4) allyltriphenyl tin; 5) tetravinyl tin; 6) vinyltrimethyl tin; 7) vinyltriphenyl tin; 8) pure methyl methacrylate.

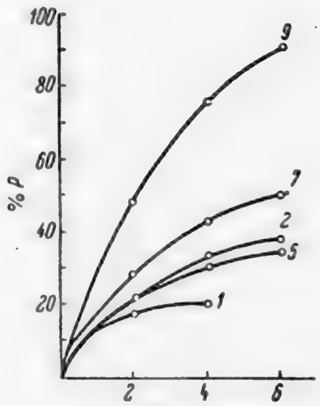


Fig. 2. Polymerization of styrene at 120° in the presence of 5 wt.% of unsaturated compounds of tin: 1) tetraallyl tin; 2) allyltrimethyl tin; 5) tetravinyl tin; 7) vinyltriphenyl tin; 9) pure styrene.

EXPERIMENTAL

Allyltriphenyl lead was prepared from triphenyl lead chloride and allylmagnesium iodide [3] in 85% yield, m. p. 75.5-76° [3].

Found %: Pb 42.91. $C_{21}H_{20}Pb$. Calculated %: Pb 43.22.

Tetravinyl tin was synthesized from vinylmagnesium bromide [8] in tetrahydrofuran and stannic chloride in 60% yield, b. p. 67-70° (28 mm), $n^{25}D$ 1.4957, d^{25}_4 1.257, independent of Seuferth [4], who published a general method for the synthesis of vinyl compounds of tin, including tetravinyl tin.

Allyltrimethyl tin was prepared from trimethyl tin bromide and allylmagnesium bromide in 25% yield [7], b. p. 128-130°, $n^{25}D$ 1.4734 [7], d^{20}_4 1.2547 [7].

Vinyltriphenyl tin was prepared from vinylmagnesium bromide in purified tetrahydrofuran and triphenyl tin chloride in 56% yield [4], m. p. 38-40° [4].

Found %: Sn 31.52. $C_{20}H_{18}Sn$. Calculated %: Sn 31.48.

Vinyltrimethyl tin was prepared in a similar manner from vinylmagnesium bromide and trimethyl tin bromide in 32% yield [4], b. p. 98-100°, $n^{25}D$ 1.4536, d^{25}_4 1.2370.

Divinyldiphenyl tin was prepared in a similar manner from vinylmagnesium bromide and diphenyl tin dichloride in 50% yield [4], b. p. 167-170° (7 mm), $n^{25}D$ 1.5947 [4], d^{25}_4 1.3280.

Reaction of allyltriphenyl lead with HCl and I_2. An ampoule containing 0.2 g of allyltriphenyl lead was cooled with dry ice, and then 1 ml of an alcohol solution of HCl was introduced into it. The ampoule was connected to a gas buret. The reaction started at room temperature. The propylene that was evolved was absorbed in a solution of bromine in CCl_4, and the solution was then titrated with $Na_2S_2O_3$. At 20° the conversion to triphenyl lead chloride (m. p. 208°) amounted to 40.5%, and at 70° it was 73.8%. When 2.34 g of allyltriphenyl lead was reacted with 1.27 g of iodine in xylene solution at room temperature, the formation of 2.78 g (98.2%) of triphenyl lead iodide with m. p. 137° (139° [9]) was observed. When the reaction was carried out at the boiling point of xylene, then a quantitative yield of lead iodide was obtained.

Found %: Pb 36.84. $C_{18}H_{15}PbI$. Calculated %: Pb 36.64.

Thermal decomposition of unsaturated compounds of tin and lead. All of the experiments were carried out by heating 1 g of the unsaturated compound of tin or lead in a sealed ampoule at 100-300°.

Allyltriphenyl lead was stable when heated for 24 hours at a temperature from 100 to 160°. At 160° and above, complete decomposition was observed, with the formation of metallic lead and tetraphenyl lead with m. p. 224°.

Vinyltriphenyl tin was unchanged when heated at 150° for 50 hours; when it was heated at 200° for 3 hours, partial symmetrization occurred (4%) with the formation of tetraphenyl tin; when it was heated at 250° for 7 hours, the formation of metallic tin and 15-20% of tetraphenyl tin was observed.

Vinyltrimethyl tin was unchanged when it was heated to 250°, but when it was heated for 3 hours at 300-310°, complete decomposition was observed with the formation of metallic tin.

Divinyldiphenyl tin was unchanged up to 200°, but when it was heated at 250-260° for 3 hours, the formation of metallic tin and tetraphenyl tin was observed. In the presence of 2% of the azodinitrile of isobutyric acid, when the temperature was raised from 60 to 100° in the course of 72 hours, the evolution of gas was observed, and 1% of a light yellow, insoluble material was formed, which did not melt up to 300°.

Found %: C 30.39; H 3.80; Sn 44.24.

Tetravinyl tin was partially decomposed upon heating for 50 hours at 170-180°, the liquid turned yellow, the $n^{25}D$ changed (from 1.5007 initially to 1.4957), and a very small amount of yellow precipitate separated out; upon heating for 3 hours at 250°, complete decomposition occurred with the formation of a gas phase and metallic tin. In the presence of 2% of the azodinitrile of isobutyric acid, heating from 60 to 100° over a period of 72 hours caused the evolution of an inflammable gas and the formation of 3% of a light yellow, insoluble material, which did not melt up to 400°.

Found %: C 15.80; H 2.70; Sn 61.70.

All of the results obtained in the study of the thermal stability of the unsaturated compounds of tin and lead are shown in Table 2.

Experiments on the polymerization and copolymerization of unsaturated compounds of tin and lead. The allyl and vinyl derivatives of tin and lead did not polymerize in mass or in benzene solution either in the absence or in the presence of various initiators (0.5% benzoyl, 0.3% tert-butyl peroxide, 0.2% azodinitrile of isobutyric acid) when heated from 60 to 160°.

All of the experiments on copolymerization of the allyl and vinyl compounds of tin with styrene and methyl methacrylate were carried out at 120° for 2, 4, and 6 hours with a ratio of 95 wt. % of the monomer to 5 wt. % of the tin derivative. The polymers obtained were dissolved in benzene, precipitated with methanol, and dried to constant weight. In all the samples of the copolymers investigated the presence of 0.4 to 2% of tin was detected.

Allyltriphenyl lead did not polymerize thermally in the absence of initiators up to 160°; in the presence of 0.1% of benzoyl peroxide or tert-butyl peroxide it did not polymerize, but at 120° it decomposed with the formation of metallic lead; in the presence of 0.1% of the azodinitrile of isobutyric acid the decomposition took place at 100°. In the presence of Ziegler catalyst decomposition started even at room temperature. When 5 wt. % of allyltriphenyl lead was added to styrene and methyl methacrylate in the presence of 0.1% of the azodinitrile of isobutyric acid at 100°, an inhibiting effect was observed, as shown in the data of Table 1.

SUMMARY

1. Under comparative conditions, the vinyl compounds of tin are more thermostable than the corresponding allyl compounds of tin, which in turn are more stable than the allyl compounds of lead.

2. The allyl derivatives of tin and lead and the vinyl derivatives of tin are not polymerized under conditions of radical polymerization.

3. The allyl derivatives of tin and lead and the vinyl derivatives of tin inhibit the radical polymerization of vinyl monomers.

LITERATURE CITED

[1] J. Brydson, Plastics 1957, 384.

[2] H. Gilman and J. Eisch, J. Org. Chem. 20, 763 (1955); J. Am. Chem. Soc. 55, 4689 (1933).

[3] P. Austin, J. Am. Chem. Soc. 53, 3514 (1931).

[4] D. Seyferth, J. Am. Chem. Soc. 79, 515, 2133 (1957); J. Org. Chem. 22, 478 (1957).

[5] S. Rosenberg, A. Gibbons, and H. Ramsder, J. Am. Chem. Soc. 79, 2137 (1957).

[6] M. M. Koton and T. M. Kiseleva, Zhur. Obshchei Khim. 27, 2553 (1957).*

[7] A. D. Petrov, V. F. Mironov, and I. E. Dolgii, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk 1956, 1146.*

[8] H. Normant, Z. ang. Chem. 67, 760 (1955).

[9] G. Gilman, J. Am. Chem. Soc. 61, 735 (1939).

* Original Russian pagination. See C. B. translation.

THE ACTION OF NITRIC ACID ON NITROOLEFINS

V. M Belikov, L. V. Ershova, and S. S. Novikov

Institute of Organic Chemistry of the Academy of Sciences of the USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 191-192, January, 1960

Original article submitted January 14, 1959

2-Nitropropene and 2-nitrobutene-1 are acted on by HNO_3 to yield unstable products [1].

We have investigated the action of nitric acid on nitroolefins that have the nitro group at the end of a chain, and especially 1-nitrobutene-1, 1-nitropropene, and nitroethylene. In this study we also obtained unstable oils; however, we were able to isolate individual products from them. It appeared that nitrates of α-hydroxy acids were mainly obtained from the reaction. Thus, the nitrate of α-hydroxybutyric acid was obtained from nitrobutylene, and the nitrate of lactic acid from nitropropylene. From nitroethylene, we obtained an extremely unstable product, from which we were unable to isolate any individual compound. The reaction apparently goes in the following way.

$$R{-}CH{=}CH{-}NO_2 \xrightarrow{HNO_3} R{-}\underset{}{\overset{\overset{\displaystyle ONO_2}{|}}{C}H}{-}CH{=}NOOH \xrightarrow{-NH_2OH} R{-}\overset{\overset{\displaystyle ONO_2}{|}}{C}H{-}COOH$$
$$R = CH_3,\ C_2H_5.$$

The structure of the products obtained was established by using the nitrate of lactic acid as an example. According to the elementary analysis the compound had the composition $C_3H_5O_5N$. Data from potentiometric titration indicated that it was a strong monobasic acid with $pK < 3$. The presence of a carboxyl group was confirmed by the formation of an amide (through the acid chloride) and an ethyl ester. The infrared spectrum of the acid contained bands at 1650, 1570, and 1290 cm^{-1}, which correspond to the vibrations of the $O-NO_2$ group, and a band at 1730 cm^{-1} which corresponds to the vibrations of the C=O bond in the carboxyl group.* We synthesized the nitrate of lactic acid for comparison with this product by a method described in [2], comprising nitration of the zinc salt of lactic acid.

The nitrate group in $CH_3CH(ONO_2)COOH$ exerts a very weak tendency toward nucleophilic substitution. This can be seen from the fact that when the nitrate was heated for 27 hours with NaI in acetone under conditions described in [3], α-iodopropionic acid was obtained only in 6% yield.

EXPERIMENTAL

Reaction of nitropropylene with HNO_3. 5 g of nitropropylene was gradually added to 30 ml of nitric acid (d 1.5) with vigorous stirring, while the temperature was maintained not higher than 40° by means of external cooling. During this process oxides of nitrogen were evolved. Stirring was continued until spontaneous evolution

* The infrared spectra were determined by V. I. Slovetskii in an IKS-11 instrument.

of heat ceased, then the mixture was poured onto ice, extracted with ether, and the ether extract was washed with water and dried over sodium sulfate. After removal of the ether in vacuo, the oil that was obtained was repeatedly washed with petroleum ether (to remove unstable products) and distilled in vacuo. The yield was 3 g (39%).*

B. p. 96° (3 mm), $n^{20}D$ 1.4356, d^{20}_4 1.3672.

The infrared spectrum contained the following bands: 840-870, 943, 1035, 1087, 1140, 1245, 1290, 1340, 1355, 1425, 1460, 1570, 1650, 1730 cm^{-1}.

Found %: C 26.36, 26.50; H 3.90, 3.86; N 9.84, 9.89. M 140. $C_3H_5O_5N$. Calculated %: C 26.67; H 3.73; N 10.37. M 135.

Amide of the nitrate of lactic acid. 1 g of the nitrate of lactic acid was heated on a water bath with 5 ml of $SOCl_2$ for 4 hours, then the excess $SOCl_2$ was distilled off in vacuo and the residue was poured into 15 ml of concentrated NH_4OH. The product was extracted with ether and formed crystals, m. p. 97-98° (from benzene). The yield was 0.3 g (31%).

Found %: C 26.55, 26.82; H 4.41, 4.48; N 20.96, 20.70. $C_3H_6O_4N_2$. Calculated %: C 26.88; H 4.51; N 20.89.

Ethyl ester of the nitrate of lactic acid. 1.3 g of the nitrate of lactic acid, 20 ml of anhydrous alcohol, and 2 drops of concentrated H_2SO_4 were heated for 8 hours on a water bath, then evaporated and poured over ice. The oil that separated out was extracted with ether, washed with sodium carbonate solution and with water, and dried over Na_2SO_4. After distillation in vacuo, 0.54 g (33%) of the ethyl ester was obtained with b. p. 82-83° (16 mm), $n^{20}D$ 1.4157.

Found %: C 36.60, 36.65; H 5.56, 5.49; N 8.80, 8.76. $C_5H_9O_5N$. Calculated %: C 36.81; H 5.56; N 8.59.

Nitration of zinc salt of lactic acid. 5 g of zinc lactate was added in small portions, with stirring, to a mixture of 4.6 ml of HNO_3 (d 1.5) and 5.5 ml of H_2SO_4 (d 1.84), stirring was continued for 1 hour more, then the mixture was poured onto ice, extracted with ether, and the ether solution was washed with water and dried over Na_2SO_4. After evaporation of the ether, the residue was distilled in vacuo. The yield was 2.3 g (52.5%). B. p. 115-115.5° (6 mm). From the acid thus obtained an amide was prepared which melted at 97-98° and gave no depression in melting point when mixed with the amide prepared from nitropropylene.

Reaction of 1-nitrobutene-1 with HNO_3. The reaction was carried out in a manner similar to that described for nitropropylene. 3.5 g (47%) of the nitrate of α-hydroxybutyric acid was obtained.

B. p. 115° (2 mm), $n^{20}D$ 1.4365, d^{20}_4 1.2849. Molecular weight determined by potentiometric titration 146.3 and 147.9. Calculated molecular weight 149. Determination of the molecular weight cryoscopically in benzene gave the double value 290, as would be expected for carboxylic acids. The IR spectrum contained the following bands: 840-870, 925, 950, 990, 1050, 1110, 1140, 1290, 1355, 1395, 1445, 1465, 1560, 1650, and 1730 cm^{-1}.

Found %: C 31.71, 31.50; H 4.78, 4.78; N 9.11, 8.90. $C_4H_7O_5N$. Calculated %: C 32.22; H 4.73; N 9.40.

Amide of the nitrate of α-hydroxybutyric acid. The amide was obtained in 90% yield. M. p. 70-72° (from a mixture of benzene and petroleum ether).

Found %: C 32.73; H 5.30; N 18.69, 18.60. $C_4H_8O_4N_2$. Calculated %: C 32.43; H 5.44; N 18.91.

* A change in the reaction temperature from 0 to 60° and in the concentration of HNO_3 to 70% did not effect the nature of the product. The conditions given afforded the maximum yield.

SUMMARY

The action of nitric acid on 1-nitroalkenes has been studied and it has been shown that under the conditions used the nitrates of α-hydroxy carboxylic acids are produced.

LITERATURE CITED

[1] M. Frankel and K. Klager, J. Org. Chem. 23, 494 (1958).

[2] H. Duval, Bull. Soc. Chim. (3), 31, 243 (1904).

[3] F. Pattison and G. Brown, Can. J. Chem. 34, 879 (1956).

ORGANIC INSECTOFUNGICIDES

LI. SYNTHESIS OF SOME O,O-DIALKYL ARYLMERCAPTOMETHYL DITHIOPHOSPHATES

K. D. Shvetsova-Shilovskaya, N. N. Mel'nikov,
M. Ya. Kagan, and V. I. Glushenkov

Scientific Institute for Fertilizers and Insectofungicides

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 193-194, January, 1960

Original article submitted January 5, 1959

Up to the present time a rather large number of O,O-dialkyl alkylmercaptomethyl dithiophosphates have been described in the literature that are rather active systemic insecticides [1], and O,O-diethylethylmercaptomethyl dithiophosphate has come into practical use for the treatment of cotton seeds to protect the young plants from attack by soil-inhabiting pests [2]. However, a serious deficiency of this group of esters is their high toxicity for warm-blooded animals, which substantially diminishes their value as insecticides and limits their practical use. According to information in [3, 4], the O,O-dialkyl arylmercaptomethyl dithiophosphates are considerably less toxic, and O,O-diethyl p-chlorophenylmercaptomethyl dithiophosphate (Trithion, USA) and O,O-diethyl-2,5-dichlorophenylmercaptomethyl dithiophosphate (Phenkapton*, Switzerland) are used in practice as acaricides and contact insecticides.

In connection with the information presented above, it was of interest to study in more detail the O,O-dialkyl arylmercaptomethyl dithiophosphates, since we might expect to obtain active insecticides among this group that would be sufficiently safe for man and domestic animals. The investigation of this group of materials was the more interesting because not more than four representatives of this series appear in the literature [3, 4].

We prepared the O,O-dialkyl arylmercaptomethyl dithiophosphates by reacting salts of the dialkyldithiophosphoric acid with a chloromethylaryl sulfide in some organic solvent, usually benzene or alcohol.

$$(RO)_2PSSMe + ClCH_2SAr \longrightarrow (RO)_2PSSCH_2SAr + MeCl$$

The compounds that we prepared and their properties are given in the table. Most of the compounds shown in the table have not been described in the literature.

An investigation of the insecticidal properties of these compounds made by P. V. Popov and N. S. Ukrainets on the granary weevil showed that O,O-dimethyl and O,O-diethyl arylmercaptomethyl dithiophosphates were the most active. As the aliphatic ester radical increased in size, the insecticidal activity decreased sharply.

EXPERIMENTAL

Preparation of the O,O-dialkyl arylmercaptomethyl dithiophosphates was carried out under the following conditions: Equimolar quantities of potassium or sodium dialkyl dithiophosphate and chloromethyl aryl sulfide were placed in a flask equipped with a reflux condenser and a mechanical stirrer. The mixture obtained was

* Name not verified.

diluted with solvent (5-6 times the amount by weight of the reactants) and boiled for 5-6 hours with efficient stirring. As the solvent we used either benzene or an alcohol having the same radical as entered into the molecule of the dialkyl dithiophosphate. After the reaction was over, the mixture was treated with water and extracted with benzene or ether; the solution obtained was washed with water and dried over calcium chloride or sulfate, the solvent was distilled off, and the material obtained was fractionated in high vacuum. The compounds synthesized and their properties are shown in the table. If the compound prepared decomposed on distillation in high vacuum, then the light fractions were distilled off from it in vacuum on a boiling-water bath and it was analyzed without further purification.

Properties of O,O-Dialkyl Arylmercaptomethyl Dithiophosphates

Formula	Yield (%)	B. p. (pressure in mm)	d_4^{20}	n_D^{20}	% P	
					found	calc.
$C_6H_5SCH_2SSP(OC_2H_5)_2$	36	128° (0.03)	1.2044	1.5909	10.21, 10.07	10.04
$C_6H_5SCH_2SSP(OC_3H_7)_2$	68	139—142 (0.08)	1.1670	1.5726	9.21	9.20*
$C_6H_5SCH_2SSP(OC_3H_7\text{-iso})_2$	73	133 (0.18)	1.1691	1.5720	9.06, 9.15	9.20
$C_6H_5SCH_2SSP(OC_4H_9)_2$	63	175 (0.15)	1.1227	1.5583	8.24, 8.15	8.49
$C_6H_5SCH_2SSP(OC_4H_9\text{-iso})_2$	49	151—152 (0.18)	1.1214	1.5673	7.72, 7.66	8.49
$4\text{-}ClC_6H_4SCH_2SSP(C_2H_5)_2$	63	143 (0.06)	1.2763	1.5932	8.97, 9.07	9.04
$4\text{-}ClC_6H_4SCH_2SSP(C_3H_7)_2$	63	180—182 (0.25)	1.2269	1.5808	8.33, 8.67	8.35
$4\text{-}ClC_6H_4SCH_2SSP(C_3H_7\text{-iso})_2$	75	Not distilled	1.2259	1.5775	7.93, 7.92	8.35
$4\text{-}ClC_6H_4SCH_2SSP(C_4H_9)_2$	65		1.1721	1.5685	7.12, 7.30	7.76

* Found %: C 46.27; H 6.57. Calculated %: C 46.69; H 6.29.

SUMMARY

In a search for effective insecticides, a number of O,O-dialkyl arylmercaptomethyl dithiophosphates have been prepared which have not previously been described in the literature. It has been established by tests that the first members of this series have rather high insecticidal activity. The activity decreases with an increase in the size of the aliphatic ester radical.

LITERATURE CITED

[1] N. Mel'nikov, Ya. Mandel'baum, and K. Shvetsova-Shilovskaya, Khim. Sredstva Zashchity Rastenii 3, 5 (1957).

[2] H. T. Reinolds, T. R. Fukuto, R. L. Metcalf, and R. B. March, J. Econ. Entomol. 50, 527 (1957).

[3] U. S. Patent 2,793,294; Chem. Abstr. 51, 14196 (1957).

[4] Fed. Rep. Germany Patent 947,369; Chem. Zentr. 128, 7157 (1957).

ORGANIC INSECTOFUNGICIDES

LII. THE REACTION OF ARYL DICHLOROTHIOPHOSPHATES WITH MAGNESIUM ETHYLATE

Ya. A. Mandel'baum, N. N. Mel'nikov, and Z. M. Bakanova

Scientific Institute for Fertilizers and Insectofungicides

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 194-197, January, 1960

Original article submitted January 5, 1959

It has recently been shown in our laboratory that when magnesium ethylate reacts with phosphorus thiotrichloride or alkyl dichlorothiophosphates, it is possible to obtain good yields of the corresponding dialkyl chlorothiophosphates [1-3]; in this process, the reaction of magnesium ethylate with phosphorus thiotrichloride goes the most easily, the reaction with alkyl dichlorothiophosphates goes somewhat more slowly, and that with dialkyl chlorothiophosphates still more slowly.

In connection with a study of methods of preparing substituted aliphatic-aromatic esters of thiophosphoric acid, which are rather widely used in agriculture for combatting plant pests, it was of interest to investigate the reaction of magnesium ethylate with aryl dichlorothiophosphates. This also was of theoretical interest, because it could provide information on the relationship of the reactivity of derivatives of the chlorothiophosphoric acids to their structure.

Our experiments, which are described in detail in the experimental section of this communication, showed that the reaction of aryl dichlorothiophosphates with magnesium ethylate may proceed according to the following paths, depending on the conditions.

$$2\,ArOPSCl_2 + (C_2H_5O)_2Mg \longrightarrow 2\,\begin{matrix} ArO \\ C_2H_5O \end{matrix}\!\!>\!PSCl + MgCl_2 \qquad (1)$$

$$2\,\begin{matrix} ArO \\ C_2H_5O \end{matrix}\!\!>\!PSCl + (C_2H_5O)_2Mg \longrightarrow 2\,ArOPS(OC_2H_5)_2 + MgCl_2 \qquad (2)$$

$$2\,ArOPS(OC_2H_5)_2 + (C_2H_5O)_2Mg \longrightarrow 2\,(C_2H_5O)_3PS + (ArO)_2Mg \qquad (3)$$

If the aryl dichlorothiophosphates are reacted with magnesium ethylate in stoichiometric proportions, then the main product of the reaction is an alkyl aryl chlorothiophosphate, which can be isolated in very satisfactory yield; the corresponding diethyl aryl thiophosphates are obtained in still better yields. Reaction (3) takes place only when a large excess of magnesium ethylate is used and the reaction mixture is heated for a long time. However, even under such conditions not all the diethyl aryl thiophosphates are capable of replacing the aryl radical by ethyl with sufficient rapidity when acted on by magnesium ethylate. The transesterification reaction goes with sufficient rapidity for the p-nitrophenyl and 2,4,5-trichloroethyl esters of diethylthiophosphoric acid, but the phenyl and p-chlorophenyl esters of this acid react with magnesium ethylate so slowly that even after heating them for 30 hours it is not possible to isolate appreciable quantities of the triethyl thiophosphate. A similar picture is observed when esters of phosphoric acid react with sodium alcoholates [4].

The activity of O,O-diethyl O-(4-nitrophenyl)thiophosphate and O,O-diethyl O-(2,4,5-trichlorophenyl)-thiophosphate in reactions with magnesium ethylate apparently is connected with the acid nature of the radicals, which, as is well known, split off comparatively easily also under the influence of alkalis [5, 6].

EXPERIMENTAL

1. Phenyl dichlorothiophosphate and magnesium ethylate. The magnesium ethylate was placed in a flask equipped with a reflux condenser, dropping funnel, and mechanical stirrer, and to it was added gradually, over a period of 20 minutes, a solution of phenyl dichlorothiophosphate in benzene (80 ml of benzene was used for each 0.1 mole). After addition of all the phenyl dichlorothiophosphate, the reaction mixture was heated for some time at 65-70°. At the end of the heating period, the mixture was diluted with water, acidified with dilute hydrochloric acid, and the benzene layer was separated off. The aqueous-alcoholic layer was repeatedly extracted with benzene, the benzene extracts were combined, washed with water, and dried, the benzene was distilled off, and the residue was fractionated in vacuo. Since the experiments were carried out under various conditions, the data for the principal ones are given below.

a) 0.1 mole of phenyl dichlorothiophosphate was used to 0.05 mole of magnesium ethylate. Heating was continued for 3.5 hours. The yield of O-ethyl O-phenyl chlorothiophosphate was 64%.

B. p. 95-100° (0.2 mm), d^{20}_4 1.2666, $n^{20}D$ 1.542.

Found %: P 13.40, 13.37; Cl 14.63. $C_8H_{10}O_2PSCl$. Calculated %: P 13.30; Cl 15.04.

b) 0.05 mole of phenyl dichlorothiophosphate was used to 0.1 mole of magnesium ethylate. Heating was continued for 7-17 hours. The yield of O,O-diethyl O-phenyl thiophosphate was 82-91%.

B. p. 120-122° (0.8 mm), 154-156° (11 mm), d^{20}_4 1.1763, $n^{20}D$ 1.5155.

Found %: P 12.48, 12.83. $C_{10}H_{15}O_3PS$. Calculated %: P 12.60.

In order to clarify the course of the transesterification, an experiment also was set up in which 0.1 mole of O,O-diethyl O-phenyl thiophosphate was heated with 0.2 mole of magnesium ethylate for 30 hours at 65-70°. After completion of the heating period and appropriate treatment, unchanged O,O-diethyl O-phenyl thiophosphate was isolated.

2. 4-Chlorophenyl dichlorothiophosphate and magnesium ethylate. The reaction of 0.3 mole of magnesium ethylate with 0.1 mole of 4-chlorophenyl dichlorothiophosphate was carried out under the conditions described above. Heating was continued for 14 and 30 hours. In all cases only O,O-diethyl O-(4-chlorophenyl)thiophosphate was isolated. The yield was 71%. B. p. 123-127° (0.25 mm), d^{20}_4 1.2240, $n^{20}D$ 1.5208.

Found %: P 10.72, 10.56. $C_{10}H_{14}O_3ClSP$. Calculated %: P 10.70.

3. 4-Nitrophenyl dichlorothiophosphate and magnesium ethylate. a) The reaction of 0.05 mole of magnesium ethylate with 0.1 mole of 4-nitrophenyl dichlorothiophosphate was carried out under the conditions described above. Heating was continued for 1.5 hours at 38-40°. O-Ethyl O-(4-nitrophenyl) chlorothiophosphate was isolated in 61% yield.

B. p. 165-170° (0.4 mm), d^{20}_4 1.4151, $n^{20}D$ 1.5810.

Found %: P 10.93, 10.85; Cl 11.82. $C_8H_9O_2NClSP$. Calculated %: P 11.06; Cl 12.61.

The O-ethyl O-(4-nitrophenyl)chlorothiophosphate prepared by a different method had close to the same constants [7].

b) 0.1-0.3 mole of magnesium ethylate and 0.1 mole of 4-nitrophenyl dichlorothiophosphate were used. Heating was continued for 3 hours at 55°. O,O-Diethyl O-(4-nitrophenyl) thiophosphate was isolated in 77-79% yield.

B. p. 156-158° (0.3 mm), d^{20}_4 1.2704, $n^{20}D$ 1.5420. According to data in [8]: d^{20}_4 1.2655, $n^{20}D$ 1.5370.

Found %: P 10.26, 10.37. $C_{10}H_{14}O_3NSP$. Calculated %: P 10.60.

c) 0.3 mole of magnesium ethylate and 0.1 mole of 4-nitrophenyl dichlorothiophosphate were used. Heating was continued for 6 hours at 60-65°. Treatment of the reaction mixture in this case differed in the following respects: After extraction with benzene, the benzene solution was extracted with an aqueous solution of sodium acetate and then further treated as described in experiment 1, but p-nitrophenol separated from the sodium carbonate solution after acidification and was extracted with ether and recrystallized from water after the ether had been removed. The yield of O,O-diethyl O-(4-nitrophenyl) thiophosphate in this experiment was 40%. p-Nitrophenol with m. p. 112° was isolated in 28% yield, and O,O,O-triethyl thiophosphate in 30% yield. B. p. 51-52° (0.3 mm), d^{20}_4 1.0746, $n^{20}D$ 1.4498, which is in agreement with the constants indicated in [9].

Found %: P 15.51, 15.38. $C_6H_{15}O_3SP$. Calculated %: P 15.65.

4. 2,4,5-Trichlorophenyl dichlorothiophosphate and magnesium ethylate. The reaction of 0.3 mole of magnesium ethylate and 0.1 mole of 2,4,5-trichlorophenyl dichlorothiophosphate was carried out under the conditions of experiment 3c. Heating was continued for 18 hours at 65-70°. O,O-Diethyl O-(2,4,5-trichlorophenyl) thiophosphate was isolated in 78% yield.

B. p. 130° (0.13 mm), d^{20}_4 1.3694, $n^{20}D$ 1.5402. According to data in [10]: d^{20}_4 1.3695, $n^{20}D$ 1.5412.

Found %: P 8.8. $C_{10}H_{12}O_3ClSP$. Calculated %: P 8.35.

2,4,5-Trichlorophenol was isolated in 13% yield. M. p. 62°.

Found %: Cl 53.1. $C_6H_3OCl_3$. Calculated %: Cl 53.83.

Triethyl thiophosphate was obtained in 15% yield.

SUMMARY

The reaction of magnesium ethylate with aryl dichlorothiophosphates has been studied. It has been shown that magnesium ethylate reacts with aryl dichlorothiophosphates according to schemes (1) and (2). In the case of 4-nitrophenyl and 2,4,5-trichlorophenyl dichlorothiophosphates a transesterification reaction also takes place according to scheme (3).

LITERATURE CITED

[1] N. N. Mel'nikov, E. I. Sventsitskii, and Z. M. Bakanova, Author's Certificate 86,533 (1950).

[2] N. N. Mel'nikov, Ya. A. Mandel'baum, Z. M. Bakanova, and V. N. Volkov, Author's Certificate 104,721 (1956).

[3] N. N. Mel'nikov, Ya. A. Mandel'baum, E. I. Sventsitskii, and Z. M. Bakanova, Zhur. Obshchei Khim. 27, 1908 (1957).*

[4] H. D. Orloff, C. J. Worrel, and F. X. Markley, J. Am. Chem. Soc. 80, 727 (1958).

[5] R. F. Hudson and L. Keoy, J. Chem. Soc. 1953, 2463.

[6] T. R. Fukuto and R. L. Metcalf, J. Agric. Food Chem. 4, 930 (1956).

[7] N. N. Mel'nikov, Ya. A. Mandel'baum, Z. M. Bakanova, and P. G. Zaks, Zhur. Obshchei Khim. 29, 3286 (1959).*

[8] N. N. Mel'nikov, Ya. A. Mandel'baum, and K. D. Shvetsova-Shilovskaya, Khim. Sredstva Zashchity Rastenii 3, 5 (1957).

[9] P. S. Pishchemuka, Zhur. Russ. Khim. Obshchestva 44, 1406 (1912).

[10] N. N. Mel'nikov and D. N. Khokhlov, Zhur. Obshchei Khim. 23, 1357 (1953).*

* Original Russian pagination. See C. B. translation.

ORGANIC INSECTOFUNGICIDES

LIII. THE REACTION OF ESTERS OF THIO- AND DITHIOPHOSPHORIC ACIDS WITH TERTIARY AMINES

N. N. Mel'nikov, K. D. Shvetsova-Shilovskaya,
and I. M. Mil'shtein

Scientific Institute for Fertilizers and Insectofungicides

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 197-199, January, 1960

Original article submitted January 19, 1959

It is well known that in recent years wide use has been made in agriculture for plant pest control of chemical agents consisting of organic compounds of phosphorus (mainly mixed esters of thio- and dithiophosphoric acids), which have almost completely supplanted such insecticides of plant origin as nicotine, anabasine, and the like. In this connection, intensive research is being carried on in various countries both to discover active new materials and to study the mechanism of action of organophosphorus compounds on insects [1, 2], since the establishment of the mechanism of action of this class of compounds should facilitate their directed synthesis.

According to present ideas, the mechanism of insecticidal and other biological action of the organic compounds of phosphorus is connected with the phosphorylation of such an enzyme as cholinesterase (or similar ones), as a result of which the normal life functions of the insect organism are disrupted [1-4]. Usually, such a phosphorylation process takes place most easily with compounds that have an electrophilic radical in their makeup, which is readily split out under the action of water or other reagents [3, 4].

However, it has recently been established in our laboratory that high insecticidal activity also is shown by some organic phosphorus compounds that do not contain such easily detachable radicals on the phosphorus [5]; moreover, the insecticidal activity changes sharply on going, for example, from the esters of phosphonoacetic acid to the esters of phosphonothioacetic acid, in which the acetic acid group ($-CH_2COOH$) is rather securely bound to the phosphorus and does not split off even on prolonged heating in acid medium [6]. In the patent literature there are also other similar examples [7].

On the basis of these observations, it was suggested that the phosphorylation of cholinesterase by means of substitution cannot be the sole explanation of the effect of organophosphorus insecticides, especially since in some pests of plants the inhibition of cholinesterase does not result in death. Another possible direction of action of the organophosphorus insecticides apparently is the formation of quaternary ammonium salts as a result of the reaction of esters of thio- and dithiophosphoric acids with tertiary nitrogen atoms present in many enzymes and also in nucleic acids.

In order to verify this hypothesis we undertook a study of the reaction of esters of thio- and dithiophosphoric acids with tertiary amines, since such compounds are not described in the literature. As a result of our experiments, we were able to establish that esters of thio- and dithiophosphoric acids react with more or less ease with tertiary amines to form the corresponding ammonium salt as the main product. The esters of thiophosphoric acid containing at least one methoxy group in the molecule, and also acid aromatic radicals,reacted the most easily.

The compounds that we prepared and their properties are shown in the table. Almost all of the compounds synthesized were readily soluble in water and were very hygroscopic. The salts prepared took up water so rapidly in an open vessel that they changed literally before our eyes in the time taken to weigh them for analysis. As can be seen from the data in the table, it was possible to prepare quaternary salts not only from the aliphatic, but also from the aromatic esters.

EXPERIMENTAL

The quaternary salts were prepared from tertiary amines and the esters of thio- and dithiophosphoric acids under the following conditions. A mixture of equimolar quantities of tertiary amine and ester of thiophosphoric acid was placed in a flask equipped with a reflux condenser having a calcium chloride tube to prevent the entrance of moisture from the air and was heated for 2-5 hours on a boiling-water bath. In the case of a solid ester of thiophosphoric acid, it was dissolved in benzene and the reaction was carried out in this solvent. After the reaction was ended, the cooled reaction mixture was washed with hot benzene and ether, and then the product which was insoluble in the organic solvent was separated and kept under vacuum of 7-10 mm on a boiling-water bath for 30 minutes. The material obtained was analyzed and its constants were determined. The density was not determined because of the very highly hygroscopic nature of the product. The compounds prepared and their properties are given in the table.

Properties of Salts of Quaternary Ammonium Bases with Thiophosphates

Formula	Yield (in %)	n_D^{20}	% P		% N	
			found	calc.	found	calc.
$(CH_3O)_3PSN(C_2H_5)_3$	67	1.5010	11.81 12.00	11.95	—	—
$C_4H_9OPS(OCH_3)_2N(C_2H_5)_3$	50	1.4905	11.04	10.30	4.45 4.39	4.70
iso -$C_5H_{11}OPS(OCH_3)_2N(C_2H_5)_3$	41	1.4892	9.55 9.56	9.82	4.04	4.47
$(C_2H_5O)_2PSOCH_3N(C_2H_5)_3$	23	1.4909	10.95 10.96	10.85	—	—
4-$O_2NC_6H_4OPS(OCH_3)_2N(C_2H_5)_3$	60	1.5650	9.07	8.50	6.98	7.70
4-$O_2NC_6H_4OPS(OC_2H_5)_2N(C_2H_5)_3$	69	1.5530	6.35	7.15	—	—
(4-$O_2NC_6H_4O)_2PSOC_2H_5N(C_2H_5)_3$	32	*	8.42 8.61	8.65	6.08 6.47	6.34
(4-$O_2NC_6H_4O)_3PSN(C_2H_5)_3$	81	**	5.64 5.61	5.37	—	—
$(CH_3O)_3PSNC_5H_5$	17	1.5416	11.30 11.75	11.18	—	—
$(CH_3O)_3PSN(CH_3)_2C_6H_5$	37	1.5490	—	—	5.51 5.69	5.95
$(CH_3O)_2PSSCHCOOC_2H_5N(C_2H_5)_3$ | $CH_2COOC_2H_5$	79	1.5100	6.48	7.17	3.02 2.81	3.24

* M. p. 67°.
** M. p. 96°.

SUMMARY

A new idea has been considered concerning the mechanism of action of insecticides on insects. In order to confirm the suggested mechanism of action of thio- and dithiophosphates on insects, a study has been made of the reaction of tertiary amines with esters of thio- and dithiophosphoric acids. It has been shown that in this reaction the salts of quaternary ammonium bases are formed in considerable yields. None of the compounds synthesized have been described in the literature previously.

LITERATURE CITED

[1] G. Schrader, Die Entwicklung neuer Insektizide auf Grundlage organischer Fluor- und Phosphor-Verbindungen. (Weinheim, 1952).

[2] J. E. Casida, J. Agr. Food Chem. 4, 772 (1956).

[3] T. R. Fukuto and R. L. Metcalf, J. Agr. Food Chem. 4, 930 (1956).

[4] T. R. Fukuto, The Chemistry and Action of Organic Phosphorus Insecticides, Advances in Pest Control Research, I. (New York, 1957).

[5] N. N. Mel'nikov, Ya. A. Mandel'baum, and V. I. Lomakina, Zhur. Obshchei Khim. 29, 3289 (1959).*

[6] A. E. Arbuzov and A. A. Dunin, Zhur. Russ. Khim. Obshchestva 46, 295 (1914); A. E. Arbuzov, Zhur. Russ. Khim. Obshchestva 59, 239 (1927).

[7] U. S. Patent 2,652,416; Chem. Abstr. 48, 10053 (1954); Fed. German Rep. Patent 938,186; Chem. Zentr. 127, 14480 (1956).

FROM THE FIELD OF ORGANIC INSECTOFUNGICIDES

LIV. NEW METHOD OF PREPARATION OF TRIALKYL DITHIOPHOSPHATES AND TETRAALKYL DITHIOPYROPHOSPHATES

N. N. Mel'nikov, K. D. Shvetsova-Shilovskaya,
and M. Ya. Kagan

Scientific Institute for Fertilizers and Insectofungicides (NIUIF)

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 200-203, January, 1960

Original article submitted January 19, 1959

Various dithiophosphoric acid esters are acquiring ever greater importance as chemical agents for the control of plant pests and also, of late, as chemical agents for the removal of leaves from cotton plants for the purpose of mechanizing cotton harvesting. Among the salts of dithiophosphoric acid diesters, potassium dibutyl dithiophosphate [1, 2] proved to be an active cotton defoliant, and tributyl trithiophosphate is considered one of the fastest-acting defoliants [3]. In connection with the above, the study of this group of compounds is of great practical interest, especially since the number of dithiophosphoric acid esters described until now is very limited.

Only a few reactions for the preparation of dithiophosphoric acid esters are described in the literature: The most important of these are the addition of acid esters of dithiophosphoric acid to the double bond of unsaturated compounds [4-6] and the interaction of alkyl halides with alkali dialkyl dithiophosphates [7-10].

In connection with the search for new insecticides and defoliants, we studied the reactions of dialkyl and trialkyl phosphites with bis(dialkylthiophosphonyl) disulfides [bis(dialkoxythiophosphon) disulfides]. It was experimentally established that the reaction of bis(dialkylthiophosphonyl)disulfides [bis(dialkoxythiophosphon)-disulfides] with dialkyl phosphites in the presence of triethylamine goes according to the following general scheme; i.e., the disulfide is reductively alkylated, and the corresponding dithiophosphoric acid esters are obtained in good yields.

$$[(RO)_2PS]_2S_2 + (R'O)_2POHN(C_2H_5)_3 \longrightarrow 2\ (RO)_2PSSR' + (C_2H_5)_3NHPO_3$$

We studied 10 instances of this reaction. The compounds obtained and their properties are given in Table 1. Only a few of these compounds are described in [7-9].

The reaction of bis(dialkylthiophosphonyl) disulfides [bis(dialkoxythiophosphon) disulfides] with trialkyl phosphites takes place with the formation both of trialkyl dithiophosphates and unsymmetrical tetraalkyl dithiopyrophosphates not previously described in the literature. This reaction may be represented by the following equation.

$$[(RO)_2PS]_2S_2 + (R'O)_3P \longrightarrow (RO)_2PSSR' + (RO)_2PSSPO(OR')_2$$

The yields of both trialkyl dithiophosphates and tetraalkyl dithiopyrophosphates in this reaction are good, but certain other substances are obtained in small amounts as byproducts. The compounds, which we obtained through the interaction of trialkyl phosphites with bis(dialkylthiophosphonyl) disulfides [bis(dialkoxythiophosphon)-disulfides], and their properties are given in Table 2.

TABLE 1

Properties of Trialkyl Dithiophosphates Prepared from Dialkyl Phosphites and bis(Dialkylthiophosphonyl) Disulfides [bis(dialkoxythiophosphon) disulfides]

Formula	Yield (in %)	B. p. (pressure in mm)	d_4^{20}	n_D^{20}	MR_D found	MR_D calc.	% P found	% P calc.
$(CH_3O)_2P(S)SCH_3$*	70	51—52° (0.2)	1.2338	1.5200	42.09	42.73	18.35, 18.31	17.98
$(C_2H_5O)_2P(S)SCH_3$	88	63.5—64 (0.08)	1.1951	1.5100	52.59	51.97	15.68, 15.41	15.47
$(C_3H_7O)_2P(S)SCH_3$	53	68—70 (0.1)	1.0806	1.5008	62.22	61.20	13.49, 13.60	13.57
$(iso\text{-}C_3H_7O)_2P(S)SCH_3$**	80	60—60.5 (0.07)	1.0736	1.4950	62.01	61.20	13.50, 14.20	13.57
$(C_4H_9O)_2P(S)SCH_3$	63	89—90 (0.08)	1.0540	1.4960	71.04	71.45	11.48, 11.39	12.08
$(iso\text{-}C_4H_9O)_2P(S)SCH_3$	78	75—76 (0.07)	1.0483	1.4930	71.06	71.45	12.40, 12.80	12.08
$(CH_3O)_2P(S)SC_2H_5$	32	48—50 (0.08)	1.1641	1.4958	46.72	47.34	17.05, 17.10	16.65
$(C_2H_5O)_2P(S)SC_2H_5$***	61	57—58 (0.08)	1.1111	1.5050	57.20	56.58	14.10	14.45
$(C_3H_7O)_2P(S)SC_2H_5$	57	73.5—75 (0.08)	1.0623	1.4968	66.23	65.82	12.70, 12.42	12.78
$(iso\text{-}C_3H_7O)_2P(S)SC_2H_5$	37	61—62 (0.08)	1.0757	1.4910	65.24	65.82	12.70, 13.10	12.78

* According to the data of [7, 8], d^{20}_4 1.2415, $n^{20}D$ 1.5292.

** According to the data of [9], d^{20}_4 1.0728, $n^{20}D$ 1.4960.

*** According to the data of [7-9], d^{20}_4 1.1168, $n^{20}D$ 1.5013.

The reaction which we studied may be regarded as a special case of the A. E. Arbuzov rearrangement, and it is a simple and convenient method for the preparation of various unsymmetrical tetraalkyl dithiopyrophosphates.

EXPERIMENTAL

1. Interaction of bis(dialkylthiophosphonyl) disulfides [bis(dialkoxythiophosphon) disulfides] with dialkyl phosphites in the presence of triethylamine. Into a flask provided with a reflux condenser, dropping funnel, and mechanical stirrer was put a benzene solution of an equimolar mixture of triethylamine and the dialkyl phosphite, and the bis(dialkylthiophosphonyl) disulfide [bis(dialkoxythiophosphon) disulfide] was gradually added with good stirring. Liquid disulfides were added without solvent, whereas solid ones were dissolved in benzene. When all the disulfide had been added, the reaction mixture was refluxed for 2 hours. The resulting solution was then cooled and decanted from the metaphosphate salt (which remained on the bottom of the flask in the form of a dense, viscous mass); the benzene was driven off and the residue distilled in vacuo. Yields and constants of the substances obtained are given in Table 1.

2. Interaction of bis(dialkylthiophosphonyl) disulfides [bis(dialkoxythiophosphon) disulfides] with trialkyl phosphites. To a solution of the bis(dialkylthiophosphonyl) disulfide [bis(dialkoxythiophosphon) disulfide] in dry benzene, an equimolar quantity of the trialkyl phosphite was gradually added with good stirring; in this case,

TABLE 2

Formula	Yield (in %)	B. p. (pressure in mm)	d_4^{20}	n_D^{20}	% P found	% P calc.	% C found	% C calc.	% H found	% H calc.
$(CH_3O)_2P(S)SC_2H_5$	Quantitative	58—59 (0.1)	1.1795	1.5080	16.20, 16.48	16.63	26.62	25.80	6.36	5.95
$(CH_3O_2)_2P(S)SP(O)(OC_2H_5)_2$	59	106—106.5 (0.1)	1.2443	1.4915	—	—	25.15, 25.00	24.49	6.04, 6.11	5.48
$(C_2H_5O)_2P(S)SC_2H_5$	84	69—71 (0.075)	1.1160	1.5020	14.65, 14.70	14.45	34.02	33.63	7.34	7.06
$(C_2H_5O)_2P(S)SP(O)(OC_2H_5)_2$	83	114—115 (0.08)	1.2054	1.5008	18.32	19.22	29.20	29.80	6.40	6.25*
$(C_3H_7O)_2P(S)SC_2H_5$	52	72—74 (0.07)	1.0638	1.4945	12.93, 13.16	12.78	—	—	—	—
$(C_3H_7O)_2P(S)SP(O)(OC_2H_5)_2$	76	112—113 (0.07)	1.1394	1.4940	16.85, 16.89	17.68	—	—	—	—
(iso $C_3H_7O)_2P(S)SC_2H_5$	62	59—60 (0.17)	1.0720	1.4900	12.71, 13.16	12.78	39.86, 39.98	39.64	7.94, 7.79	7.90
(iso $-C_3H_7O)_2P(S)SP(O)OC_2H_5)_2$	87	117—118 (0.18)	1.1435	1.4915	—	—	33.68, 34.03	34.28	6.48, 7.53	6.90
$(C_4H_9O)_2P(S)SC_2H_5$	70	86—88 (0.08)	1.0400	1.4923	11.26, 11.53	11.46	—	—	—	—
$(C_4H_9O)_2P(S)SP(O)(OC_2H_5)_2$	68	123—124 (0.07)	1.1060	1.4908	15.73, 15.70	16.37	38.71	38.09	7.72	7.46
$(C_2H_5O)_2P(S)SC_3H_7$	70	72.5—73 (0.08)	1.0901	1.4990	13.97, 14.17	13.57	—	—	—	—
$(C_2H_5O)_2P(S)SP(O)(OC_3H_7)_2$	38	123 (0.1)	1.1477	1.4872	16.62	17.68	34.88, 34.76	34.28	6.47, 7.39	6.90
$(C_3H_7O)_2P(S)SC_3H_7$	65	74—76 (0.11)	1.0349	1.4860	12.19, 12.08	12.08	—	—	—	—
$(C_3H_7O)_2P(S)SP(O)(OC_3H_7)_2$	60	125—127 (0.08)	1.0917	1.4865	15.33	16.37	—	—	—	—
(iso $-C_3H_7O)_2P(S)SC_3H_7$	83	67.5—68.5 (0.075)	1.0459	1.4848	12.48, 11.90	12.08	41.74	42.16	8.50	8.27
(iso $-C_3H_7O)_2P(S)SP(O)(OC_3H_7)_2$	72	126.5—127 (0.15)	1.1166	1.4905	15.92, 15.85	16.37	—	—	—	—

* Found %: S 19.25, 19.39. Calculated %: S 19.89.

the reaction mixture evolved heat and the temperature increased 20-30°. When all the trialkyl phosphite had been added, the reaction mixture was boiled for 2 hours in a water bath in a flask provided with a reflux condenser. When the reaction was finished, the benzene was driven off and the residue fractionated in vacuo. Each resulting fraction of the substance was redistilled for purification, and analyzed. The compounds which we obtained and their properties are given in Table 2.

SUMMARY

1. A new method has been developed for the preparation of full esters of dithiophosphoric acid by treating bis(dialkylthiophosphonyl) disulfides [bis(dialkoxythiophosphon) disulfides] with dialkyl phosphites in the presence of triethylamine.

2. The interaction of bis(dialkylthiophosphonyl) disulfides [bis(dialkoxythiophosphon) disulfides] with trialkyl phosphites was studied, and it was shown that trialkyl dithiophosphates and tetraalkyl dithiopyrophosphates are obtained in good yields through this reaction.

3. Most of the phosphorus acid esters synthesized by the new methods are not described in the literature.

LITERATURE CITED

[1] L. I. Korolev, V. A. Voitekhova, and L. D. Stonov, Vestnik S. Kh. Nauki 3, 82 (1958).

[2] N. N. Mel'nikov, Trudy NIUIF 158, 297 (1958).

[3] Anonymous, Agr. Chem. 13, 5, 111 (1958).

[4] N. N. Mel'nikov and K. D. Shvetsova- Shilovskaya, Zhur. Obshchei Khim. 23, 1352 (1953).*

[5] I. L. Vladimirova and N. N. Mel'nikov, Zhur. Obshchei Khim. 26, 2569 (1956).*

[6] N. N. Mel'nikov and K. D. Shvetsova-Shilovskaya, Doklady Akad. Nauk SSSR 86, 543 (1952).

[7] M. I. Kabachnik and T. A. Mastryukova, Izvest. Akad. Nauk SSSR 1954, 436.*

[8] M. I. Kabachnik and T. A. Mastryukova, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk 1952, 727.*

[9] G. R. Norman, W. M. Le Suer, and T. W. Mastin, J. Am. Chem. Soc. 74, 161 (1952).

[10] German Fed. Republic Patent 850,677; Chem. Abstr. 47, 4034 (1953).

* Original Russian pagination. See C. B. translation.

INVESTIGATIONS IN THE PYRAZOLE SERIES

V. SYNTHESIS OF 4-BENZOYLPYRAZOLES

I. I. Grandberg and A. N. Kost

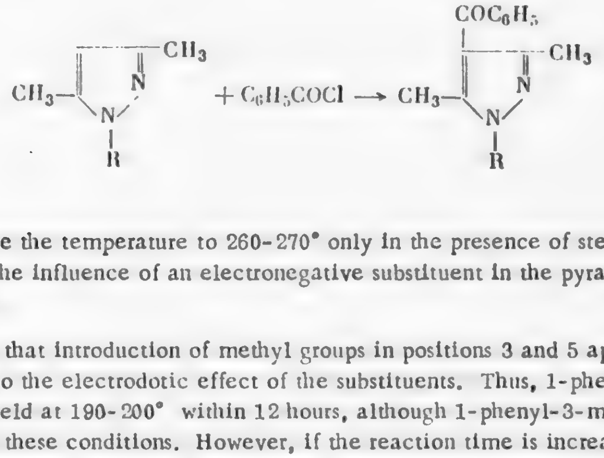
Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 203-208, January, 1960

Original article submitted December 8, 1958

Balbiano [1] stated that 1-phenylpyrazole is acylated on heating to 250-260° with benzoyl chloride, 1-phenyl-4-benzoylpyrazole presumably being formed. Similarly, he benzoylated 1,3,5-triphenylpyrazole [2]. Later, Auwers [3] benzoylated 1,5-diphenyl- and 1-phenyl-5-p-tolylpyrazoles under similar conditions; however, he did not attempt to determine the structures of the substances formed.

We investigated this reaction in somewhat greater detail. It was found that the reaction with benzoyl chloride, as a rule, can also take place under milder conditions (190-200°), both 1-phenyl- and 1-alkylpyrazoles reacting. For instance, 1-methyl, 1-ethyl-, 1-phenyl-, and 1-benzyl-3,5-dimethylpyrazoles reacted smoothly with benzoyl chloride, giving high yields (67-94%), even when they were simply heated to boiling (about 190°).

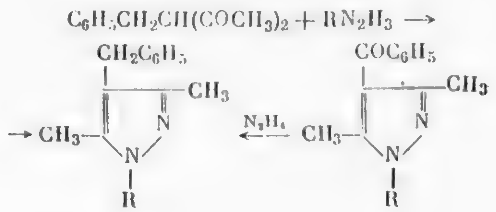


It is necessary to raise the temperature to 260-270° only in the presence of steric hindrance (1,3,5-triphenylpyrazole) or under the influence of an electronegative substituent in the pyrazole nucleus (1-phenyl-3-methyl-5-chloropyrazole).

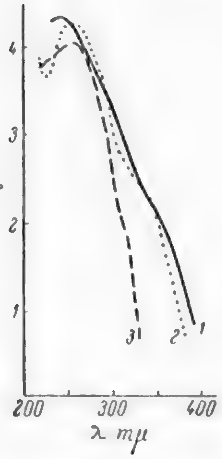
It is of great interest that introduction of methyl groups in positions 3 and 5 appreciably facilitates the reaction, obviously owing to the electrodotic effect of the substituents. Thus, 1-phenyl-3,5-dimethylpyrazole is benzoylated with 83% yield at 190-200° within 12 hours, although 1-phenyl-3-methylpyrazole reacts only to the extent of 12% under these conditions. However, if the reaction time is increased to 30 hours, the yield increases to 60%. On heating 3,5-dimethylpyrazole with benzoyl chloride to 200° for 20 hours we isolated only 1-benzoyl-3,5-dimethylpyrazole, although it is stated in [1] that 1,4-dibenzoyl-3,5-dimethylpyrazole could be obtained at 250° (6 hours).

For proof of structure of the benzoylpyrazoles obtained, we decided to reduce them to benzylpyrazoles. Clemmensen reduction gave unusually stable complexes with zinc chloride; the benzylpyrazoles could not be liberated from them. An attempt at reduction with hydriodic acid also was unsuccessful. 4-Benzylpyrazoles were synthesized through the Kizhner reduction with no particular difficulty.

We countersynthesized the 4-benzylpyrazoles through the condensation of benzyldiacetylmethane with the corresponding alkylhydrazines.



The absorption spectra* of all 4-benzoylpyrazoles investigated have an absorption band in the 243-255 mμ region (log ε 4.2).



Absorption curves of benzoylpyrazoles in ultraviolet light. 1) 1,3,5-triphenyl-4-benzoylpyrazole (λ_{max} 243, log ε 4.342); 1-phenyl-3-methyl-4-benzoylpyrazole (λ_{max} 247, log ε 4.305); 1-phenyl-3-methyl-5-chloro-4-benzoylpyrazole (λ_{max} 260, log ε 4.415); 2) 1,3,5-trimethyl-4-benzoylpyrazole (λ_{max} 250, log ε 4.262); 1-benzyl-3,5-dimethyl-4-benzoylpyrazole (λ_{max} 251, log ε 4.103); 1-ethyl-3,5-dimethyl-4-benzoylpyrazole (λ_{max} 250, log ε 4.130); 1-phenyl-3,5-dimethyl-4-benzoylpyrazole (λ_{max} 245, log ε 4.267); 3) 1-benzoyl-3,5-dimethylpyrazole (λ_{max} 255, log ε 4.041).

It is a noteworthy fact that introduction of a benzoyl radical in position 4 of the phenylpyrazole molecule causes practically no shift of the absorption band toward longer wavelengths (the absorption maximum lies near 250 mμ for various phenylpyrazoles [4]). At the same time introduction of a benzoyl radical in the 1-alkylpyrazole nucleus shifts the absorption band 30-40 mμ toward longer wavelengths (from 210-225 mμ [4] to 240-255 mμ). Hence, after a phenyl group has been substituted in any position in the nucleus of pyrazole (having λ_{max} 220 mμ [4]), the absorption maximum is shifted to the 250 mμ region [4]; further introduction of phenyl or benzoyl substituents causes practically no shift of the maximum. Typical examples of the curves are shown in the figure.

EXPERIMENTAL

1,3,5-Trimethylpyrazole. A 520 g quantity of hydrazine sulfate was mixed with 1000 ml of water in a 3-liter beaker, and 400 g of acetylacetone was then added during 0.5 hour with vigorous stirring. When mixing was complete, the mixture was left to stand for 4 hours and then cautiously made alkaline with 480 g of solid sodium hydroxide, the temperature being kept around 70-80° by cooling. As soon as the addition of alkali was finished at 70-80°, 512 g of dimethyl sulfate was gradually added, the temperature being kept near 80°. The mixture was then stirred for 2 hours, another 500 g of solid sodium hydroxide and 300 ml of benzene were added, and then, after one-half hour, the upper, oil layer was separated. It was dried with fused potassium hydroxide and distilled. Yield of 1,3,5-trimethylpyrazole, 348 g (79%), b. p. 165-176° (747 mm) [5]. In order to free this, as well as other 1-alkylpyrazoles, from an admixture of nonalkylated pyrazole we used the following procedure. Four ml of alcoholic 20% sodium ethoxide solution and 0.2 mole of acrylonitrile were added to 1 mole of the pyrazole. The mixture was heated in a water bath for 1 hour and the 1-methylpyrazole distilled off in the vacuum of a water-jet pump, in the boiling bath. After redistillation, b. p. 165-167° (741 mm); picrate, m. p. 148° [5].

1-Benzyl-3,5-dimethylpyrazole. A 122 g quantity of benzylhydrazine was gradually added to 100 g of acetylacetone. When the violent reaction was finished, the mixture was refluxed for 1 hour. Then 200 ml of benzene

* The absorption spectra were taken with an SF-4 spectrophotometer. Solvent — methanol.

was added, and the benzene layer was separated and was fractionated in vacuo. There was obtained 165 g (81%) of 1-benzyl-3,5-dimethylpyrazole.

B. p. 154-156° (18 mm), $n^{20}D$ 1.5472, d^{20}_4 1.0378, MR_D 56.93; Calc. 57.59.

Picrate, m. p. 123-124° (from 80% alcohol) [5].

Found %: N 16.83, 16.68. $C_{12}H_{14}N_2 \cdot C_6H_3O_7N_3$. Calculated %: N 16.86.

1-Phenyl-3-methyl-5-chloropyrazole. A mixture of 130 g of acetoacetic ester, 108 g of phenylhydrazine, 100 ml of water, and 100 ml of acetic acid was refluxed for 5 hours. The reaction mass was then poured into 200 ml of water, and the precipitated crystals of the pyrazolone were filtered out on the next day. They were dried in a drying oven at 80°. The dry pyrazolone was mixed with 75 ml of anhydrous pyridine, 115 ml of phosphoryl chloride was cautiously added, and the mixture was heated for 6 hours at 160° in a flask with a reflux condenser. The reaction mass was poured into ice, made alkaline with potash, and extracted with benzene; the extracts were dried with magnesium sulfate and fractionated in vacuo. There was obtained 137 g (71.5%) of 1-phenyl-3-methyl-5-chloropyrazole.

B. p. 140° (15 mm), $n^{20}D$ 1.5774, d^{20}_4 1.1901, MR_D 53.67; Calc. 53.22 [6].

1-Ethyl-3,5-dimethylpyrazole. A mixture of 28.8 g of 3,5-dimethylpyrazole and 109.2 g of ethyl iodide was heated in a sealed tube at 100° for 8 hours. The reaction mass was made alkaline with an excess of 40% sodium hydroxide and then extracted with benzene. The benzene was distilled from the extract, and the residue was purified by means of acrylonitrile (as described above). There was obtained 21.2 g (58%) of pure 1-ethyl-3,5-dimethylpyrazole.

B. p. 169-172° (751 mm), $n^{20}D$ 1.4731, d^{20}_4 0.9181, MR_D 37.95; Calc. 38.01.

Picrate, m. p. 128° (from alcohol) [7].

1-Phenyl-3,5-dimethylpyrazole was prepared by the method described above for 1-benzyl-3,5-dimethylpyrazole, in 90% yield. B. p. 157-161° (24 mm) [5].

1,3,5-Trimethyl-4-benzoylpyrazole. A mixture of 10.6 g of 1,3,5-trimethylpyrazole and 44 g of benzoyl chloride was refluxed for 12 hours; the reaction mass was then heated to boiling with an excess of concentrated aqueous potash solution until the benzoyl chloride odor was gone, and was extracted with benzene. On fractionation of the benzene extracts 20.1 g (94%) of 1,3,5-trimethyl-4-benzoylpyrazole was obtained.

B. p. 201° (13 mm), $n^{20}D$ 1.5803, d^{20}_4 1.1272, MR_D 61.98; Calc. 62.22.

Found %: C 72.44, 72.53; H 6.83, 6.97; N 12.87, 12.97. $C_{13}H_{14}ON_2$. Calculated %: C 72.86; H 6.59; N 13.07.

Picrate, m. p. 135-136° (from 80% alcohol).

Found %: N 15.59, 15.65. $C_{13}H_{14}ON_2 \cdot C_6H_3O_7N_3$. Calculated %: N 15.79.

1-Ethyl-3,5-dimethyl-4-benzoylpyrazole. This was prepared similarly from 1-ethyl-3,5-dimethylpyrazole in 67% yield.

B. p. 198-200° (13 mm), $n^{20}D$ 1.5726, d^{20}_4 1.1101, MR_D 67.11; Calc. 66.84.

Found %: C 73.77, 73.89; H 7.80, 7.81; N 12.20, 12.41. $C_{14}H_6ON_2$. Calculated %: C 73.66; H 8.07; N 12.27.

Picrate, m. p. 106° (from 80% alcohol).

Found %: N 15.12, 15.31. $C_{14}H_{16}ON_2 \cdot C_6H_3O_7N_3$. Calculated %: N 15.31.

1-Benzyl-3,5-dimethyl-4-benzoylpyrazole was prepared as described above from 1-benzyl-3,5-dimethylpyrazole in 84% yield; b. p. 244-252° (13 mm), m. p. 95° (from a benzene–petroleum ether mixture).

Found %: C 78.22, 78.33; H 6.45, 6.56; N 9.42, 9.89. $C_{19}H_{18}ON_2$. Calculated %: C 78.58; H 6.26; N 9.64.

The picrate, m. p. 84-85° (from absolute ether), decomposed on recrystallization from alcohol.

Found %: N 13.33, 13.33. $C_{19}H_{18}ON_2 \cdot C_6H_3O_7N_3$. Calculated %: N 13.23.

1-Phenyl-3,5-dimethyl-4-benzoylpyrazole was prepared as described above from 1-phenyl-3,5-dimethylpyrazole in 83% yield; b. p. 254-257° (23 mm), m. p. 99-100° (from petroleum ether). It did not give a picrate.

Found %: C 78.19, 78.49; H 6.06, 5.91; N 10.34, 10.43. $C_{18}H_{16}ON_2$. Calculated %: C 78.28; H 5.84; N 10.14.

1-Phenyl-3-methyl-4-benzoylpyrazole was prepared as described above from 1-phenyl-3-methylpyrazole [4], but heating was continued for 30 hours. Yield 60%. When the reaction time was decreased to 12 hours, the yield fell to 12%. B. p. 238-243° (28 mm), m. p. 136° (from petroleum ether). It did not give a picrate.

Found %: C 77.59, 77.69; H 5.76, 5.89. $C_{17}H_{14}ON_2$. Calculated %: C 77.84; H 5.39.

1-Phenyl-3-methyl-4-benzoyl-5-chloropyrazole was prepared by the method described above from 1-phenyl-3-methyl-5-chloropyrazole, but the reaction was carried out in a sealed tube for 8 hours at 260-270°. Yield 53%. When the reaction was carried out in an open vessel, the reaction mixture being refluxed for 12 hours, the yield was nil.

B. p. 247-254° (22 mm), m. p. 85-86° (from petroleum ether) [8]. It did not give a picrate.

1,3,5-Triphenyl-4-benzoylpyrazole was prepared as described above from 1,3,5-triphenylpyrazole [4], but the reaction was carried out in a sealed tube for 10 hours at 270°. Yield 81%. When the reaction was carried out in an open vessel, the reaction mixture being refluxed for 12 hours, the yield was nil. M. p. 171-172° (from petroleum ether) [2]. It did not give a picrate.

Found %: N 7.10, 7.16. $C_{28}H_{20}ON_2$. Calculated %: N 6.99.

When 3,5-dimethylpyrazole was heated for 20 hours with a three-fold quantity of benzoyl chloride at 200°, a quantitative yield of 3,5-dimethyl-1-benzoylpyrazole was obtained.

Attempts at replacement of benzoyl chloride in the reaction by p-nitrobenzoyl chloride, toluenesulfonyl chloride, and isonicotinyl chloride hydrochloride were unsuccessful. The reaction mass was completely resinified after boiling for 1 hour. 1-Phenyl-3-acetamidopyrazole could not be acylated, either. On heating at 200° for 2 hours with benzoyl chloride, part of it was recovered unchanged, whereas on heating for 10 hours, it was completely resinified.

1,3,5-Trimethyl-4-benzylpyrazole. A mixture of 4 g of 1,3,5-trimethyl-4-benzoylpyrazole, 5 ml of butanol, and 5 ml of hydrazine hydrate was heated in a sealed tube at 200° for 12 hours. Then the excess hydrazine and butanol were driven off, and the remainder of the reaction mass was decomposed over 0.2 g of potassium hydroxide, and distilled. There was obtained 3.4 g (84%) of 1,3,5-trimethyl-4-benzylpyrazole, b. p. 294°, m. p. 55° (from petroleum ether). Picrate, m. p. 135-136° (from 70% alcohol).

Found %: C 53.01, 53.03; H 4.37, 4.38. $C_{13}H_{16}N_2 \cdot C_6H_3O_7N_3$. Calculated %: C 53.45; H 4.27.

1,3,5-Trimethyl-4-benzylpyrazole was countersynthesized through the condensation of benzyldiacetylmethane [9] with methylhydrazine sulfate. The pyrazole gave a picrate with m. p. 134-135° (from 70% alcohol), which did not give a melting-point depression with the picrate described above.

1-Phenyl-3,5-dimethyl-4-benzylpyrazole. This was prepared as described above by Kizhner reduction. Picrate, m. p. 111-112° (from 80% alcohol).

Found %: N 14.36, 14.52. $C_{18}H_{18}N_2 \cdot C_6H_3O_7N_3$. Calculated %: N 14.25.

The countersynthesis was carried out through the condensation of benzyldiacetylmethane with phenylhydrazine. The pyrazole gave a picrate with m. p. 111-112° (from 80% alcohol), which did not give a melting-point depression with the picrate of the pyrazole obtained by the Kizhner reduction of 1-phenyl-3,5-dimethyl-4-benzoylpyrazole.

1,4-Dibenzyl-3,5-dimethylpyrazole was prepared similarly by the Kizhner reduction of 1-benzyl-3,5-dimethyl-4-benzoylpyrazole. Picrate, m. p. 131-132° (from 70% alcohol).

Found %: C 59.08, 59.14; H 4.27, 4.33. $C_{19}H_{20}N_2 \cdot C_6H_3O_7N_3$. Calculated %: C 59.40; H 4.59.

1,4-Dibenzyl-3,5-dimethylpyrazole was countersynthesized through the condensation of benzyldiacetylmethane with benzylhydrazine. The pyrazole gave a picrate with m. p. 131-132° (from 70% alcohol), which did not give a melting-point depression with the picrate of the pyrazole obtained by Kizhner reduction.

Attempt at reduction of 4-benzoylpyrazoles. A 5.8 g quantity of 1-benzyl-3,5-dimethyl-4-benzoylpyrazole was dissolved in 50 ml of concentrated hydrochloric acid, and 10 g of amalgamated zinc was added. In the process of heating, the complex precipitated in the form of a very viscous, yellowish, noncrystallizing oil. It was insoluble in water and nonpolar solvents. It was very soluble in alcohol and acetone. It did not decompose on treatment with hot solutions of acids and alkalis. Other benzoylpyrazoles behaved similarly. Moreover, benzopyrazoles were not reduced on boiling for 10 hours with concentrated hydriodic acid solution and red phosphorus.

SUMMARY

It has been shown that heating of pyrazoles having a free 4-position in the nucleus to 200-250° with benzoyl chloride may be used as a preparative method for the synthesis of 4-benzoylpyrazoles.

LITERATURE CITED

[1] L. Balbiano, Gazz. 19, 139 (1886).

[2] L. Balbiano and J. Marchetti, Ber. 26R, 600 (1893).

[3] K. Auwers and H. Mauss, J. pr. Chem. (2), 117, 311 (1927).

[4] I. I. Grandberg and A. N. Kost, Zhur. Obshchei Khim. 29, 658 (1959).*

[5] K. Auwers and H. Broche, Ber. 55, 3910 (1922).

[6] A. Michaelis and H. Behn, Ber. 33, 2606 (1900).

[7] K. Auwers and W. Daniel, J. pr. Chem. (2), 110, 248 (1925).

[8] A. Michaelis and F. Beuder, Ber. 36, 524 (1903).

[9] G. Morgan and C. Taylor, J. Chem. Soc. 1925, 801.

* Original Russian pagination. See C. B. translation.

INVESTIGATIONS IN THE PYRAZOLE SERIES

VI. SYNTHESIS OF 1-ALKYLPYRAZOLES WITH UNSYMMETRICALLY ARRANGED SUBSTITUENTS IN THE NUCLEUS

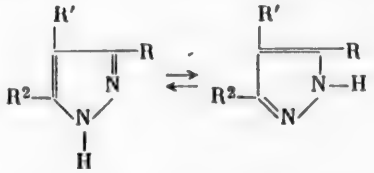
I. I. Grandberg and A. N. Kost

Moscow State University

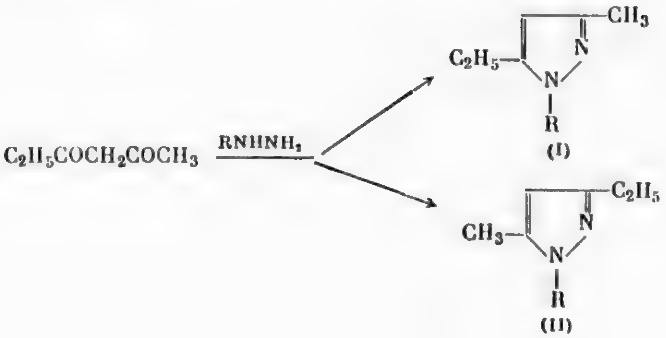
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 208-212, January, 1960

Original article submitted January 9, 1959

Pyrazoles unsubstituted in position 1 display tautomerism due to migration of the hydrogen atom [1-3].

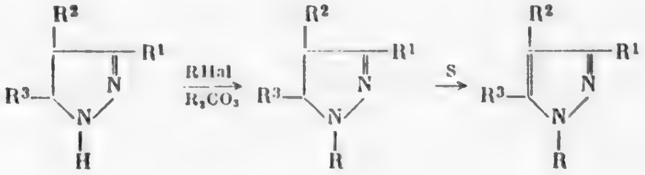


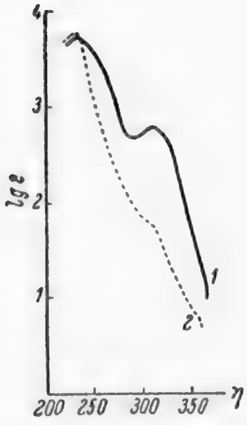
If this hydrogen atom is substituted, the tautomerism naturally vanishes; for instance, 1,3-dimethylpyrazole is not tautomeric with 1,5-dimethylpyrazole [6]. In connection with this, if the pyrazole has a nucleus which is unsymmetrical with respect to the two nitrogen atoms, its N-alkylation nearly always leads to a mixture of the two possible isomers [4, 5]. One of the isomers is formed preferentially only in the case where the substituents in positions 3 and 5 are substantially different in character [6]. Auwers investigated this problem but did not reach any final conclusions. In a number of cases, his data are contradictory [5-7]. Other methods for the synthesis of 1-alkylpyrazoles, such as, for instance, the interaction of alkylhydrazines with β-dicarbonyl compounds and their derivatives [6], also lead nearly always to a mixture of the two possible isomers (I) and (II), which is very difficult to resolve.



Until now, therefore, a sufficiently convenient and general method for the synthesis of 1-alkylpyrazoles, in which the substituents in the nucleus are unsymmetrically arranged with respect to the two nitrogen atoms, has not been available.

Pyrazolines do not have tautomerism of the pyrazole type [1, 8], and therefore the alkylation of pyrazolines always leads to a single isomer (aside from the possible stereoisomer). Practicable methods for the synthesis of pyrazolines being available [9, 10], we developed a procedure for N-alkylation of the latter by treatment with alkyl halides in the presence of potash, followed by dehydrogenation to 1-alkylpyrazoles by the method described by us earlier [11].





UV spectra of 1-alkylpyrazoles. The spectra of 1-isoamyl-4-isopropyl-5-isobutyl-, 1-butyl-4-isopropyl-5-isobutyl-, and 1,5-diisobutyl-4-isopropylpyrazoles correspond to Curve 1. The spectra of all the rest of the pyrazoles given in Table 2 correspond to Curve 2.

1-Alkylpyrazolines are colorless, mobile liquids with a characteristic odor. Alkylation of the nitrogen atom decreases the refractive index of pyrazoline from 1.46 to 1.45 and lowers the specific gravity three units in the second decimal place (see Table 1), but the boiling points of the 1-alkylpyrazolines are very slightly increased, obviously owing to decreased association. The corresponding 1-alkylpyrazoles have somewhat higher refractive indices (about five units in the third decimal place) and higher specific gravities (see the data of Tables 1 and 2). The 1-alkylpyrazole picrates are viscous, noncrystallizing oils, insoluble in water and petroleum ether and very soluble in alcohol and ether. The hydrochlorides also are noncrystallizing oils. The picrolonates crystallize with very great difficulty (only after standing for several days) and are recrystallized from 80% alcohol, as is the single solid picrate obtained. The ultraviolet absorption spectra of the 1-alkylpyrazoles obtained have a pronounced absorption band in the 230 mμ region (figure and Table 2), i.e., a spectral region of greater wavelength than in the case of pyrazoles unsubstituted in position 1 [11], whose maximum lies at about 220 mμ. 1-Alkyl-4-isopropyl-5-isobutylpyrazoles have a second maximum in the 306 mμ region, whereas 4-isopropyl-5-isobutylpyrazole, which is not substituted on nitrogen, does not have this maximum [11]. On calculating the molar refraction for 1-alkylpyrazolines (Table 1) we used a group refraction equal to 6.245 for two nitrogen atoms together with a double bond. For 1-alkylpyrazoles (Table 2) we used the same group refraction, and besides, the refraction of one double bond.

EXPERIMENTAL

3-Methyl-5-isopropylpyrazoline. Fifty-six g of isobutyralacetone [12], 26 g of hydrazine hydrate, and 50 g of methanol were mixed in a flask provided with a reflux condenser. Then the mixture was refluxed for 3 hours, 50 ml of benzene added, and the mixture fractionally distilled. There was obtained 46.5 g (74%) of 3-methyl-5-isopropylpyrazoline.

B. p. 88-90° (21 mm), $n^{20}D$ 1.4640, d^{20}_4 0.9111, MR_D 38.21; Calc. 38.20.

Phenylthiocarbamide derivative: m. p. 112° (from petroleum ether).

Found %: C 64.33, 64.15; H 7.45, 7.36. $C_{14}H_{19}N_3S$. Calculated %: C 64.38; H 7.37.

TABLE 1

1-Alkylpyrazolines

Pyrazoline	Yield (in %)	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D found	MR_D calc.	Molecular formula	% C found	% C calc.	% H found	% H calc.
1-Butyl-4-ethyl-5-propyl-	64.5	128°(19)	1.4590	0.8674	61.87	61.66	$C_{12}H_{24}N_2$	73.36, 73.28	73.42	12.35, 12.11	12.34
1-Isobutyl-4-ethyl-5-propyl-	79	118 (20)	1.4568	0.8650	61.74	61.66	$C_{12}H_{24}N_2$	73.21, 73.14	73.42	12.55, 12.63	12.34
1-Isoamyl-4-ethyl-5-propyl-	53	140 (27)	1.4580	0.8646	66.34	66.28	$C_{13}H_{26}N_2$	73.98, 73.91	74.23	12.46, 12.31	12.48
1,5-Dipropyl-4-ethyl-	74	116 (21)	1.4560	0.8647	57.27	57.04	$C_{11}H_{22}N_2$	72.58, 72.63	72.47	12.39, 12.47	12.17
1-Butyl-4-isopropyl-5-isobutyl-	68	135 (28)	1.4532	0.8536	70.88	70.90	$C_{14}H_{28}N_2$	74.63, 74.82	74.93	12.65, 12.72	12.58
1,5-Diisobutyl-4-isopropyl-	24.5	115 (26)	1.4526	0.8551	70.84	70.90	$C_{14}H_{28}N_2$	74.66, 74.82	74.93	12.60, 12.68	12.58
1-Isoamyl-4-isopropyl-5-isobutyl-	32	138 (25)	1.4528	0.8502	75.76	75.52	$C_{15}H_{30}N_2$	75.62, 75.51	75.57	12.78, 12.97	12.69
1-Isoamyl-3-methyl-4-isopropyl-	63	122 (26)	1.4566	0.8611	62.05	61.66	$C_{12}H_{24}N_2$	73.29, 73.16	73.42	12.46, 12.11	12.34
1-Propyl-3-ethyl-4-methyl-	69	82 (18)	1.4560	0.8641	47.88	47.80	$C_9H_{18}N_2$	69.93, 70.03	70.08	11.58, 11.63	11.76

TABLE 2

1-Alkylpyrazoles

Pyrazole	Yield (in %)	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D found	MR_D calc.	Molecular formula	% N found	% N calc.	λ_{max} mμ	lg ε	M. p. of picrolonate
1-Butyl-4-ethyl-5-propyl-	61.0	126° (18)	1.4691	0.8912	60.74	61.19	$C_{12}H_{22}N_2$	14.43,* 14.21	14.35	230	4.041	111.5—112.5°
1-Propyl-3-ethyl-4-methyl-	64.3	88 (18)	1.4639	0.8890	47.25	47.33	$C_9H_{16}N_2$	—**	—	230	3.740	86—87***
1-Isoamyl-3-methyl-5-isopropyl-	67.5	116 (16)	1.4704	0.8948	60.63	61.19	$C_{12}H_{22}N_2$	14.11, 14.09	14.35	228	3.720	116—117
1,5-Dipropyl-4-ethyl-	64.5	116 (16)	1.4658	0.8840	56.46	56.58	$C_{11}H_{20}N_2$	15.40, 15.34	15.53	229	3.732	123—124
1-Isoamyl-4-ethyl-5-propyl-	68.0	131 (16)	1.4682	0.8893	65.15	65.81	$C_{13}H_{24}N_2$	13.21, 13.07	13.45	229	3.763	100—101
1-Isobutyl-4-ethyl-5-propyl-	66.0	119 (16)	1.4654	0.8841	60.81	61.19	$C_{12}H_{22}N_2$	14.48, 14.29	14.35	227	4.201	73—74
1-Isoamyl-4-isopropyl-5-isobutyl-	66.5	122 (18)	1.4558	0.8553	75.11	75.04	$C_{15}H_{28}N_2$	11.57, 11.62	11.84	233 306	3.694 2.365	153—154
1-Butyl-4-isopropyl-5-isobutyl-	64.0	121 (17)	1.4558	0.8517	70.50	70.42	$C_{14}H_{26}N_2$	12.24, 12.31	12.59	234 306	3.700 2.491	136—137
1,5-Diisobutyl-4-isopropyl-	64.0	123 (18)	1.4583	0.8668	70.04	70.42	$C_{14}H_{26}N_2$	12.37, 12.42	12.59	230 309	3.716 2.723	110—111

* Found %: C 74.54, 74.36; H 11.54, 11.61. Calculated %: C 74.18; H 11.45.

** Found %: C 71.15, 71.27; H 10.85, 10.64. Calculated %: C 71.00; H 10.60.

*** Melting point of the picrate.

3-Ethyl-4-methylpyrazoline was prepared by the method of A. N. Kost and V. V. Ershov [10].

4-Isopropyl-5-isobutylpyrazoline. Into a flask provided with a large Dimroth condenser was put 611 g of freshly distilled isovaleraldehyde; the flask being cooled with ice water, 185 g of hydrazine hydrate was cautiously added dropwise without allowing the mixture to boil too vigorously. After cooling, the upper, oil layer was separated and was shaken in a funnel with 30 g of finely ground anhydrous magnesium sulfate for 15 minutes. Then the dry azine was put into a 1-liter flask with a reflux Dimroth condenser, and 50 ml of anhydrous formic acid was immediately added. If the mixture did not begin to boil spontaneously within 10 minutes, the flask was heated to boiling, and the mixture was then kept boiling by adding another 130 ml of anhydrous formic acid (as a result of the exothermic reaction). When all the acid had been added, the mixture was boiled for 2 hours more. The entire reaction mass was put into a large porcelain dish and evaporated with 900 ml of concentrated hydrochloric acid until the residue became thick. The operation was repeated with 400 ml of acid. The viscous residue was made alkaline with 400 ml of concentrated ammonia solution, and the oil layer was separated and dried with magnesium sulfate. On distillation, 298 g (50%) of 4-isopropyl-5-isobutylpyrazoline, b. p. 123-129° (25 mm), $n^{20}D$ 1.4652, d^{20}_4 0.8971 [9], was obtained.

4-Ethyl-5-propylpyrazoline. This was similarly prepared from 653 g of butyraldehyde. Yield 230 g (36.5%), b. p. 106-114° (19 mm), $n^{20}D$ 1.4641, d^{20}_4 0.9087 [9].

Alkylation of pyrazolines. A mixture of 1 mole of the pyrazoline, 1.25 moles of finely ground anhydrous potash, slightly moistened with water, and 1.05 moles of the alkyl bromide were refluxed for 14-16 hours. Water was then poured into the cold reaction mass until the salts dissolved, and the oil layer was separated, dried with magnesium sulfate, and purified by fractional distillation in vacuo. The constants of the 1-alkylpyrazolines obtained are given in Table 1.

Dehydrogenation of pyrazolines. One-tenth mole of the pyrazoline and 0.105 mole of sulfur were boiled in a flask with a small reflux condenser until the evolution of hydrogen sulfide ceased (about one-half hour), and the reaction mass was then distilled twice in vacuo. The constants of the 1-alkylpyrazoles obtained are given in Table 2.

SUMMARY

A method has been developed for synthesizing 1-alkylpyrazoles with unsymmetrically arranged substituents (on the third and fourth or the fourth and fifth atoms of the pyrazole ring) by alkylating the corresponding pyrazolines and then dehydrogenating the product.

LITERATURE CITED

[1] K. Auwers and P. Heimke, Lieb. Ann. 458, 186 (1927).

[2] L. Knorr, Ber. 28, 688 (1895).

[3] L. Knorr, Lieb. Ann. 279, 217 (1894).

[4] K. Auwers and W. Schmidt, Ber. 58, 528 (1925).

[5] K. Auwers and H. Stuhlmann, Ber. 59, 1043 (1926).

[6] K. Anwers and H. Hollmann, Ber. 59, 1282 (1926).

[7] K. Auwers and H. Broche, Ber. 55, 3880 (1922).

[8] K. Freudenberg and W. Stoll, Lieb. Ann. 440, 38 (1924).

[9] A. N. Kost and I. I. Grandberg, Zhur. Obshchei Khim. 26, 2319 (1956).*

* Original Russian pagination. See C. B. translation.

[10] A. N. Kost and V. V. Ershov, Zhur. Obshchei Khim. 27, 1722 (1957).*

[11] I. I. Grandberg and A. N. Kost, Zhur. Obshchei Khim. 28, 3071 (1958).*

[12] R. Hellmann, G. Gaudemaris, P. Arnaud, and G. Scheuerbraund, Bull. Soc. Chim. (5), 112 (1957).

* Original Russian pagination. See C. B. translation.

SYNTHESIS OF CIS-HOMOCINCHOLOIPON

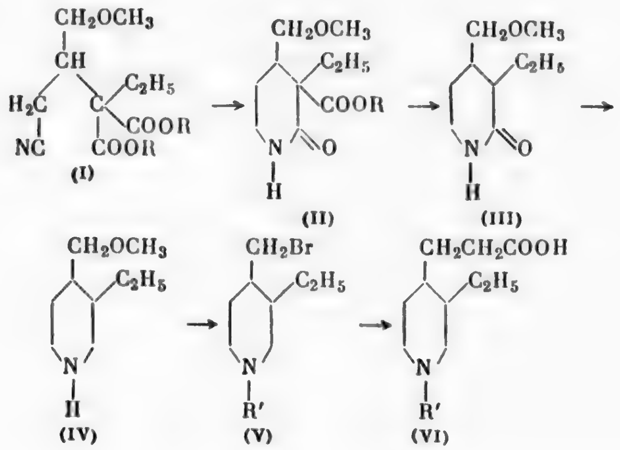
Yu. F. Malina, R. P. Evstigneeva, and N. A. Preobrazhenskii

Moscow Institute of Fine Chemical Technology

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 213-216, January, 1960

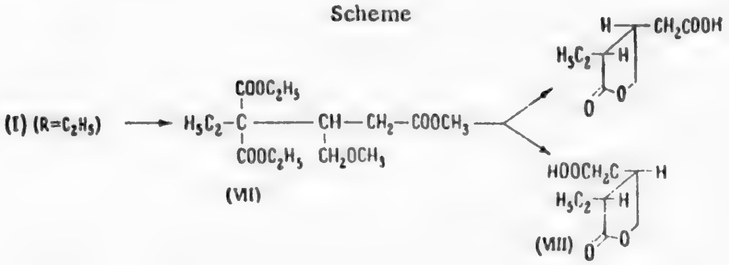
Original article submitted December 26, 1958

In the preceding article the synthesis of cis- and trans-homocincholoipons, proceeding from diethyl β-(α'-cyano)propylglutarate, was described in [1]. We investigated several possible routes of preparation of homocincholoipon in order to find the most practicable method of synthesis. In the present work the synthesis of cis-homocincholoipon (VI, R' = H) from ethyl α-ethyl-α-carbethoxy-β-methoxymethylglutarate mononitrile [2] (I, R = C_2H_5) is described.



On reduction of ethyl α-ethyl-α-carbethoxy-β-methoxymethylglutarate mononitrile (I, R = C_2H_5) in the presence of Raney nickel catalyst, 3-ethyl-3-carbethoxy-4-methoxymethylpiperidone-2 (II, R = C_2H_5) was obtained in two isomeric forms: 1) b. p. 175-177° (1 mm) and 2) b. p. 210-215° (1 mm).

Scheme



For the rest of the synthesis only the first of these, which led to cis-homocincholoipon was used. Hydrolysis of piperidone (II, $R = C_2H_5$) with potassium hydroxide in an aqueous-alcoholic medium gave acid (II, R = H). After decarboxylation, 3-ethyl-4-methoxymethylpiperidone-2 (III) was obtained. Reduction of (III) with lithium aluminum hydride led to 3-ethyl-4-methoxymethylpiperidine (IV). Treatment of the latter with hydrobromic acid gave 3-ethyl-4-bromomethylpiperidine (V, R' = H), from which 1-nitroso-3-ethyl-4-bromomethylpiperidine (V, R' = NO) was then prepared. Condensation of (V, R' = NO) with malonic ester and subsequent hydrolysis and decarboxylation gave 1-nitroso-3-ethylpiperidyl-4-propionic acid (VI, R' = NO). The nitroso group was removed by heating (VI, R' = NO) with cuprous chloride. cis-Homocincholoipon (VI, R' = H) was obtained as a result.

Investigations in the field of cis- and trans-homocincholoipons made it possible for us to take up the synthesis of other compounds containing in the initial intermediate product a grouping of carbon atoms, of the same type as in quinine, namely, that of homopilopic acid (the primary substance for preparation of the alkaloid pilocarpine), which was synthesized according to the scheme given above.

EXPERIMENTAL

Synthesis of homopilopic acid (VIII). Ethyl α-ethyl-α-carbethoxy-β-methoxymethylglutarate mononitrile (I, $R = C_2H_5$) was esterified by means of methanol saturated with hydrogen chloride, methyl γ,γ-dicarbethoxy-β-methoxymethylcaproate (VII) being formed.

B. p. 172-174° (6 mm), d^{15}_4 1.078, $n^{15}D$ 1.4450, MR_D 78.48. $C_{15}H_{26}O_7$. Calc. 78.07.

On hydrolysis of ester (VII) with hydrochloric or 40% hydrobromic acid a mixture of diastereoisomeric α-ethylhomoparaconic acids with m. p. 48-60° (VIII) was obtained, one of which (m. p. 102-103°) was rac. homopilopic acid and the other (m. p. 73-74°), rac. homoisopilopic acid.

3-Ethyl-3-carbethoxy-4-methoxymethylpiperidone-2 (II, $R = C_2H_5$). Fifteen g of ethyl α-ethyl-α-carbethoxy-β-methoxymethylglutarate mononitrile in 50 ml of anhydrous ethanol was hydrogenated in the presence of 2 g of Raney nickel catalyst at 105 atm and 160° for 1 hour. The catalyst was filtered out, the solvent removed, and the residue distilled. Two fractions were isolated: the 1st, 5.8 g (45.5%), and the 2nd, 4.9 g (38.3%).

First fraction: b. p. 175-177.5° (1 mm), d^{20}_4 1.1016, $n^{20}D$ 1.4785. MR_D 62.58; Calc. 62.32.

Found %: C 59.17, 59.50; H 8.30, 8.68; N 5.89, 6.02. $C_{12}H_{21}O_4N$. Calculated %: C 59.25; H 8.64; N 5.72.

Second fraction: b. p. 210-215° (1 mm), d^{20}_4 1.1100, $n^{20}D$ 1.4845. MR_D 62.76; Calc. 62.32.

Found %: C 59.53, 59.20; H 8.89, 8.81; N 5.30, 5.47. $C_{12}H_{21}O_4N$. Calculated %: C 59.25; H 8.64; N 5.72.

3-Ethyl-4-methoxymethylpiperidone-2 (III). A 5.8 g quantity of 3-ethyl-3-carbethoxy-4-methoxymethylpiperidone-2, b. p. 175-177.5° (1 mm), 4.5 g of potassium hydroxide, 20 ml of methanol, and 10 ml of water were heated at 105° for 12 hours. The alcohol was distilled off in vacuo and the aqueous solution acidified with concentrated hydrochloric acid. The potassium chloride was filtered out, the water driven off in vacuo, and the residue heated in vacuo at 120° for 30 minutes and distilled. Yield 2.5 g (62.5%).

B. p. 150-152° (1 mm), d^{20}_4 1.0521, $n^{20}D$ 1.4810, MR_D 46.32; Calc. 46.81.

Found %: C 63.18, 62.98; H 9.75, 9.84; N 8.10, 8.33. $C_9H_{17}O_2N$. Calculated %: C 63.15; H 9.94; N 8.18.

3-Ethyl-4-methoxymethylpiperidine (IV). To a suspension of 2 g of lithium aluminum hydride in 50 ml of anhydrous dioxane, a solution of 2.3 g of 3-ethyl-4-methoxymethylpiperidone-2 in 30 ml of anhydrous dioxane was added. The mixture was heated with continuous stirring for 5 hours. The excess lithium aluminum hydride was decomposed with 40% sodium hydroxide solution. The dioxane layer was separated and the alkaline solution extracted with dioxane (three times with 30-ml portions). The combined extracts were dried with potassium carbonate. The solvent was removed and the residue distilled. Yield 1.35 g (65.2%).

B. p. 63-64° (1 mm), d^{20}_4 0.9229, $n^{20}D$ 1.4665, MR_D 47.23; Calc. 46.82.

Found %: C 68.33, 68.49; H 12.19, 12.11; N 8.71, 9.01. $C_9H_{19}ON$. Calculated %: C 68.78; H 12.10; N 8.92.

1-Nitroso-3-ethyl-4-bromomethylpiperidine (V, R' = NO). Two g of 3-ethyl-4-methoxymethylpiperidine (IV) was heated for 7 hours with 8.7 ml of 47% hydrobromic acid. The excess hydrobromic acid was distilled off in vacuo, the residue was dissolved in 5 ml of water, and 0.66 g of sodium nitrite in 2.5 ml of water was added. The mixture was heated to 80° and cooled, and the separated oil was extracted with ether. The extract was washed with saturated sodium bicarbonate solution and dried with sodium sulfate. After solvent removal, 1-nitroso-3-ethyl-4-bromomethylpiperidine was obtained in the form of a viscous, yellow, noncrystallizing oil. Yield 1.7 g (56.6%).

3-Ethyl-4-carboxyethylpiperidine, cis-homocincholoipon (VI, R' = H). A 1.7 g quantity of 1-nitroso-3-ethyl-4-bromomethylpiperidine (V, R' = NO) was heated for 4 hours with the sodiomalonate obtained from 3.7 g of malonic ester, 0.54 g of metallic sodium, and 7.7 ml of anhydrous alcohol. The excess alcohol was distilled off in vacuo, and the residue was dissolved in 5 ml of water, neutralized with dilute (1:3) acetic acid, and extracted with ether. After removal of the ether, 1.8 g of a substance was obtained, which was then heated with 2.06 g of potassium hydroxide and 10 ml of water for 30 minutes. The solution was extracted with ether in order to remove unhydrolyzed 1-nitroso-3-ethylpiperidine-4-methylmalonic ester, acidified with dilute (1:2) hydrochloric acid, and again extracted with ether. The solvent was distilled off, and the residue (0.85 g) was heated for 15 minutes in vacuo at 160° and then thoroughly extracted with 100 ml of ether. After solvent removal a yellow, noncrystallizing oil was obtained; the latter was heated with 1.5 ml of concentrated hydrochloric acid and 0.1 g of cuprous chloride until nitrogen oxides ceased to be evolved (5 minutes). The hydrochloric acid was distilled off in vacuo, and the residue was dissolved in 8 ml of water and heated with 5 g of sodium hydroxide for 10 minutes. The cuprous oxide was filtered out, the aqueous solution acidified with concentrated hydrochloric acid, the solvent removed, and the dry residue extracted with alcohol. After the alcohol was driven off, a viscous, noncrystallizing oil was obtained; 0.14 g of the latter was dissolved in 0.5 ml of concentrated hydrochloric acid and treated with 0.18 g of auric chloride dissolved in 2 ml of water. The yellow-orange cis-homocincholoipon chloroaurate crystals which precipitated were filtered out and were dried in a vacuum desiccator. Yield 0.11 g, m. p. 165-165.5°. The product was recrystallized from 3 ml of hydrochloric acid and then from 3 ml of dilute (1:1) methanol, and was dried in a vacuum desiccator. M. p. 172-172.5°.

Found %: C 23.10, 22.86; H 3.56, 3.96; Au 37.22, 37.46. $C_{10}H_{20}O_2NCl_4Au$. Calculated %: C 22.80; H 3.81; Au 37.60.

A mixed sample of cis-homocincholoipon chloroaurate (m. p. 172-172.5°) prepared by us proceeding from ethyl α-ethyl-α-carbethoxy-β-methoxymethylglutarate mononitrile, and cis-homocincholoipon chloroaurate (m. p. 174.5-175°) prepared from diethyl β-(α'-cyano)propylglutarate [1], melted at 172-173.5°.

SUMMARY

1. A synthesis of cis-homocincholoipon, based on ethyl α-ethyl-α-carbethoxy-β-methoxymethylglutarate mononitrile, was carried out.

2. It was shown that cinchona alkaloids and pilocarpine alkaloids may be synthesized by using identical starting materials and transformations of the same type.

LITERATURE CITED

[1] R. P. Evstigneeva, Yu. F. Malina, and N. A. Preobrazhenskii, Izvest. Vyssh. Uchebn. Zaved. MVO SSSR, Khim. i Khim. Tekhnol., 5, 46 (1958).

[2] C. F. Koelsch, J. Am. Chem. Soc. 65, 2460 (1943); 68, 146 (1946).

INVESTIGATIONS IN THE FIELD OF CONJUGATED SYSTEMS

CXIII. ON ADDITION OF ALKYLLITHIUMS TO VINYLALKYLACETYLENES*

V. A. Kormer and A. A. Petrov

Lensovet Leningrad Institute of Technology

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 216-219, January, 1960

Original article submitted December 23, 1958

In the preceding works of our laboratory regularities were established in the reactions of addition of a number of electrophilic and nucleophilic reagents to vinylacetylenic hydrocarbons of various structures [1]. Certain experiments in the probably radical-type chloroarylation of vinylacetylene and vinylethylacetylene also are described. Addition of aryl and chlorine took place at the ethylenic bond and in the 1,4-position [2].

In order to obtain further material on reactions of addition to vinylacetylenes we undertook a systematic study of the addition of organolithium compounds to the hydrocarbons named above.

There were no data on this subject in the literature. Only the addition of alkyllithiums to certain aryl-olefins, cyclooctatetraene, olefins, and diolefins had been studied [3, 4]. In the first case monomeric addition products, and in the last two cases mixtures of telomers, had been obtained. The structure of the adducts was usually judged from the structure of the hydrocarbons or acids formed on treatment of the reaction mixture with water or carbon dioxide. In every case, the radical became attached to the least substituted of the carbon atoms at the ends of the double bond.

In a preliminary article [5], we showed that ethyllithium and butyllithium readily add to vinylmethyl- and vinylethylacetylenes at room temperature with the formation of adducts which, when treated with water, give disubstituted allenic hydrocarbons and a higher-boiling residue containing ethylenic hydrocarbons.

Further experiments showed that at diminished temperatures (lower than $-30°$) only allenic hydrocarbons, which distill with practically no residue are obtained, regardless of the nature of the alkyllithium.

We investigated the addition of primary [$Li-C_2H_5$, $Li-C_3H_7$, $Li-C_4H_9$, $Li-CH_2-CH(CH_3)_2$], secondary [$Li-CH(CH_3)_2$], and tertiary [$Li-C(CH_3)_3$] alkyllithiums to vinylmethyl- and vinylethylacetylenes and in all cases obtained the disubstituted allenic hydrocarbons, whose formulas and constants are given in Table 1, in good yields. None of them are described in the literature.

From Table 1 it is evident that displacement of the allenic system toward the center of the molecule leads to a certain increase in the boiling point and has practically no effect on the specific gravity and refractive index. Chain branching causes a marked lowering of the boiling point and some decrease in the specific gravity and refractive index. All disubstituted allenes display exaltation of the molar refraction, which increases as the radicals become more branched.

---

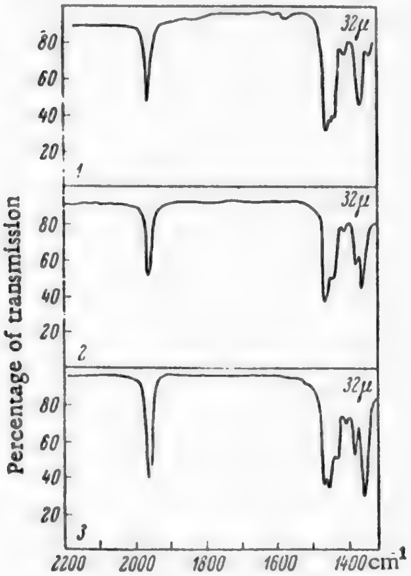
* Enyne compounds. XXXVI.

In each case the addition of alkyllithiums to vinylalkylacetylenes could be expected to result in the formation of six products with three types of multiple bonds: the 1,3-dienic system (1,2-addition), the allenic grouping (1,4-addition), and the acetylenic bond (3,4-addition) [5].

TABLE 1

Substance	B. p. (pressure in mm)	d_4^{20}	n_D^{20}	MR_D	
				found	calc.
$CH_3-CH=C=CH-CH_2-CH_2-CH_3$ (I)	52—53°(150)	0.7274	1.4360	34.57	33.59
$CH_3-CH=C=CH-CH_2-CH_2-CH_2-CH_2-CH_3$ (II)	64—65 (40)	0.7555	1.4454	43.79	42.83
$CH_3-CH=C=CH-CH_2-CH_2-CH(CH_3)_2$ (III)	62—63 (40)	0.7525	1.4450	43.93	42.83
$CH_3-CH=C-CH-CH_2-C(CH_3)_3$ (IV)	52—53 (40)	0.7452	1.4418	44.08	42.83
$CH_3-CH_2-CH=C=CH-CH_2-CH_2-CH_3$ (V)	77.5—78.5 (150)	0.7443	1.4432	39.26	38.21
$CH_3-CH_2-CH=C=CH-CH_2-CH_2-CH_2-CH_3$ (VI)	67—68 (40)	0.7542	1.4458	43.90	42.83
$CH_3-CH_2-CH=C=CH-CH_2-CH(CH_3)_2$ (VII)	60—60.5 (40)	0.7488	1.4430	43.98	42.83
$CH_3-CH_2-CH=C=CH-CH_2-CH_2-CH_2-CH_2-CH_3$ (VIII)	82.5—83.5 (40)	0.7655	1.4498	48.51	47.45
$CH_3-CH_2-CH=C=CH-CH_2-C(CH_3)_3$ (IX)	70—70.5 (40)	0.7555	1.4458	48.78	47.45

The nature of the multiple bonds in the hydrocarbons obtained was quite definitely established by studying their infrared spectra. In these spectra only the band of the allenic grouping (1960 cm^{-1}) occurred. The bands of the acetylenic bond (2100-2300 cm^{-1}) and the 1,3-dienic system (1600-1680 cm^{-1}) did not occur at all.



IR transmission spectra. 1) Nonadiene-2,3; 2) 7-methyloctadiene-2,3; 3) 6,6-dimethylheptadiene-2,3.

Depending on the position of the radical, allenic hydrocarbons could have either the formulas given in Table 1 or formulas of the type $R_2C=C=CH-R$.

The choice between these two formulas was made on the basis of data on the catalytic hydrogenation of the allenes obtained. Five hydrocarbons were hydrogenated; saturated hydrocarbons, corresponding in structure to the allenes given in Table 1, being obtained in all cases. The hydrogenation products were identified through their constants and through their infrared spectra by comparing the latter with the spectra of known samples of saturated hydrocarbons; in one case, we used samples of both possible hydrogenation products (heptane and 3-methylhexane).

The strongly marked direction of addition of alkyllithiums to vinylalkylacetylenes and the absence of side reactions apparently are due to the small low-temperature reactivity of organolithium compounds with the lithium atom at the double bond, both in reactions of further addition to vinylalkylacetylenes (telomerization) and in the tautomeric conversion

$$R-CLi=C=CH-CH_2-R' \rightleftarrows R-C\equiv C-CHLi-CH_2-R'$$

The present work showed that the addition of alkyllithiums to vinylalkylacetylenes may be used for the synthesis of various disubstituted allenic hydrocarbons.

EXPERIMENTAL

The vinylalkylacetylenes were prepared by the usual method [6]. The alkyllithiums were synthesized from alkyl chlorides, usually in absolute ether, by a well-known procedure [7]. The alkyllithium solutions used had concentrations of 0.9-1.0 N; the latter were determined by double titration.

TABLE 2

Original hydrocarbon	R in LiR	Solvent	Temp.	Yield of allene (in %)	Residue (in g)
$CH_3C{\equiv}C-CH{=}CH_2$	C_2H_5	Petroleum ether	29°	16.2	10
	C_2H_5	Ether	—40	72	—
	n $-C_4H_9$	Petroleum ether	40	16.1	8.5
	iso $-C_4H_9$	Ether	—40	58	—
	tert $-C_4H_9$	Same	—40	50.6	—
$C_2H_5-C{\equiv}C-CH{=}CH_2$	C_2H_5	Petroleum ether	40	27.3	5
	C_2H_5	Ether	10	36.4	10
	n $-C_3H_7$	Same	—10	74.2	—
	iso $-C_3H_7$	Same	—40	80.5	—
	n $-C_4H_9$	Petroleum ether	30	16.0	5
	tert $-C_4H_9$	Ether	—40	52.2	—

Into a three-neck flask provided with a stirrer, reflux condenser, and thermometer (which had been flushed out with nitrogen beforehand), 0.25 mole of the alkyllithium in ethereal solution and then 0.25 mole of the hydrocarbon in a 1 : 1 mixture with the same solvent were introduced from a Schlenk vessel, with a countercurrent of nitrogen. When the reagents were mixed, the temperature rose. At the end of the reaction (usually within 1-1.5 hours) the contents of the flask were poured into ice water. The upper hydrocarbon layer was washed with water until a neutral reaction was obtained, dried with aluminum oxide, and distilled. Certain experimental data are given in Table 2, and analytical data in Table 3.

TABLE 3

Hydrocarbon	Found (%)		Calculated (%)	
	C	H	C	H
C_7H_{12} (I)	87.58, 87.74	12.38, 12.38	87.42	12.58
C_9H_{16} (II)	86.90, 87.39	12.39, 12.89	87.02	12.98
C_9H_{16} (III)	86.93, 87.12	12.88, 12.99	87.02	12.98
C_9H_{16} (IV)	86.88, 87.01	13.01, 12.96	87.02	12.98
C_8H_{14} (V)	86.81, 86.73	12.51, 12.41	87.19	12.81
C_9H_{16} (VI)	87.05, 87.01	12.93, 13.05	87.02	12.98
C_9H_{16} (VII)	87.08, 86.88	12.93, 12.06	87.02	12.98
$C_{10}H_{18}$ (VIII)	87.44, 87.31	12.72, 12.75	86.88	13.12
$C_{10}H_{18}$ (IX)	86.75, 86.84	13.14, 13.15	86.88	13.12

In Table 4 are given the constants of the saturated hydrocarbons obtained from the allenes by catalytic hydrogenation on colloidal palladium. They agreed closely with [8]. Somewhat greater discrepancies were observed in the case of products obtained from vinylmethylacetylene; this may have been due to an admixture of several percent of isomeric allenes.

The infrared spectra of three allenes in the 1300-2200 cm^{-1} region are given in the figure. The infrared spectra of the disubstituted allenes are discussed in detail in a separate article [9].

TABLE 4

Hydrocarbon	Original allene	Boiling point	d_4^{20}	n_D^{20}
n-Heptane	(I)	98—99°	0.6833	1.3880
n-Octane	(V)	125—126	0.7021	1.3980
2-Methyloctane	(III)	140—142	0.7133	1.4040
2-Methyloctane	(VII)	141—143	0.7133	1.4038
n-Decane	(VIII)	172—174	0.7324	1.4125

SUMMARY

1. The reaction of vinylalkylacetylenes with alkyllithiums was investigated for the first time.

2. It was shown that at diminished temperatures alkyllithiums smoothly add to vinylalkylacetylenes with the formation of disubstituted allenic hydrocarbons.

3. The structure of the addition products was proved through the infrared spectra and on the basis of data on hydrogenation to the corresponding saturated hydrocarbons.

4. A new method for synthesizing disubstituted allenic hydrocarbons has been proposed.

LITERATURE CITED

[1] A. A. Petrov and co-workers, Zhur. Obshchei Khim. 20, 708 (1950);* 23, 1471, 1867 (1953);* 24, 803 (1954);* 26, 407, 1926, 3319 (1956);* 27, 365, 1805, 2076 (1957);* 28, 1999 (1958);* 29, 1153, 1878, 2278, 2281, 2830, 3738, 3999 (1959);* Doklady Akad. Nauk SSSR 90, 561 (1953), 95, 285 (1954); 119, 292 (1958);* NDVSh 1, 335 (1958).

[2] A. A. Petrov, Yu. I. Kheruze, et al., Zhur. Obshchei Khim. 29, 2101 (1959).*

[3] A. D. Petrov, E. B. Sokolova, and Kao Ch'ing-lang, Uspekhi Khim. 27, 1471 (1958).

[4] P. D. Bartlett, S. Fridman, and M. Stibes, J. Am. Chem. Soc. 75, 1771 (1953).

[5] A. A. Petrov and V. A. Kormer, Doklady Akad. Nauk SSSR 125, 1041 (1959).*

[6] R. A. Jacobson and W. H. Carothers, J. Am. Chem. Soc. 55, 1624 (1933).

[7] K. A. Kocheshkov and T. V. Talalaeva, Synthetic Methods in the Field of Organometallic Compounds of Lithium [In Russian] (Acad. Sci. USSR Press, 1949).

[8] R. D. Obolentsev, Physical Constants of Hydrocarbons [In Russian] (Gostoptekhizdat, 1953).

[9] A. A. Petrov, T. V. Yakovleva, and V. A. Kormer, Optika i Spektroskopiya 7, 267 (1959).

* Original Russian pagination. See C. B. translation.

THE REARRANGEMENT OF HYDROXYBENZILS.

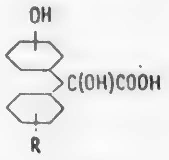
I. N. Somin and S. G. Kuznetsov

Institute of Toxicology, Academy of Medical Sciences, USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 220-227, January, 1960

Original article submitted January 13, 1959

In the present work we undertook the synthesis of hydroxy- and dihydroxybenzilic acids, which are of some potential interest for the preparation of new cholinolytic pharmaceuticals. For the purpose of synthesis, we chose the benzil rearrangement of the corresponding hydroxy- and dihydroxybenzils.

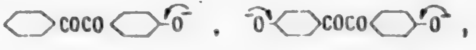


R = H, OCH_3, OH,

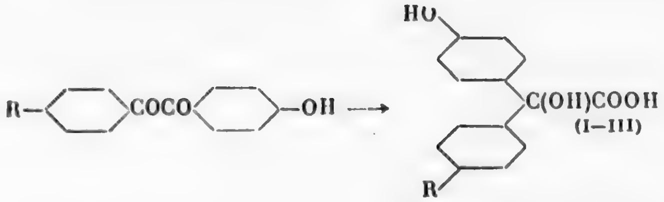
The literature contains only isolated and contradictory references to the possibility of rearrangement of hydroxybenzils. Asahina and Asano [1] attempted to rearrange 2-hydroxy- and 2,4'-dihydroxybenzils and obtained syrupy products to which they assigned the structure of the corresponding benzilic acids. Pearl [2] unsuccessfully attempted to rearrange 4,4'-dihydroxy-3,3'-dimethoxybenzil. In 1956 Pfeil, et al., [3] wrote that "hydroxybenzils in general scarcely react with aqueous alkalies," although they succeeded in rearranging 5,5'-dibromo-2,2'-dihydroxybenzil.

It is known in general that introduction of electron-donating substituents (Alk, OAlk) into benzil or phenanthrenequinone leads to a decrease in the migrating ability of the radicals containing these substituents; the speed of rearrangement of the benzil then decreases. On the other hand, the introduction of an electron-accepting substituent (Cl) has the opposite effect [3-6]. The position of the substituent in the ring also has an appreciable influence. The following order of migrating abilities of radicals and of rates of rearrangement is applicable in all cases investigated: meta > para > ortho [3, 5-7].

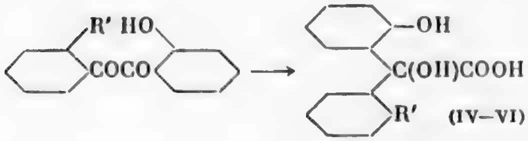
Rearrangement takes place in an alkaline medium; under these conditions hydroxybenzils exist in the form of the cations



which contain extraordinarily strong electron-donating substituents. The sharp fall in rate of transformation of hydroxy- and (in particular) dihydroxybenzils relative to other benzils is therefore not unexpected. Nevertheless, the above-quoted statement of Pfeil et al. could not be confirmed. We succeeded in rearranging six hydroxybenzils by boiling them in aqueous alkali solutions.



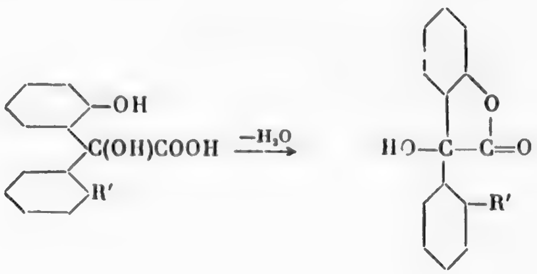
(I) R = H, (II) R = OCH_3, (III) R = OH.



(IV) R′ = H, (V) R′ = OCH_3, (VI) R′ = OH.

The yields of the corresponding substituted benzilic acids (I, II), (IV-VI) are nearly quantitative. Acid (III), however, was obtained in good yield only by treatment of 4,4′-dihydroxybenzil with an alkaline melt, containing 73% alkali and 27% water, at 125-150°. This treatment was also found convenient for preparation of the remaining acids.

Hydroxybenzilic acids (I-III), containing hydroxy groups in para-positions, are easily crystallizing and stable substances (Table 1). Acids (IV-VI), with hydroxy groups in ortho positions, were found to be labile compounds which easily change into the corresponding lactones.

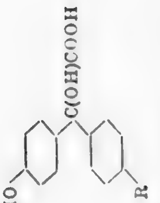


Lactonization proceeds quantitatively when gentle heat is applied; it is speeded up in presence of mineral acids. We were unable to obtain acids (IV) and (VI) in crystalline form. Acid (V) crystallizes with facility but its melting point is unsharp due to rapid lactonization on heating. Acids (IV-VI) were characterized in the form of the silver salts from which were also prepared the corresponding methyl esters. Data for these acids and their derivatives are presented in Table 2.

In the course of the investigation, it was noted that benzils containing hydroxyl groups in the ortho-position rearrange more rapidly than the corresponding para-derivatives. We followed up this observation by a number of experiments with the objective of qualitative evaluation of the relative influence of the position and of the number of hydroxyl groups on the rate of rearrangement. In these experiments (Table 3) several pair of hydroxybenzils were subjected to rearrangement under identical conditions.

TABLE 1

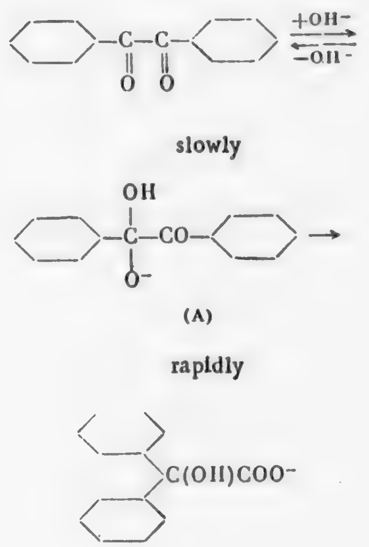
Hydroxybenzilic Acids



Acid	R	Yield (in %)*	Melting point (decomp)	Solvent for recrystallization	Color with conc. H_2SO_4	Found (%) C	Found (%) H	Found (%) OH	Calculated (%) C	Calculated (%) H	Calculated (%) OH
I	H	90.5	165—166°	Water	Orange	68.47, 69.24	5.21, 4.89	21.59, 20.96	68.84	4.95	20.89
II	OCH_3	89.5	153—154	Water	Crimson	65.51, 65.27	5.47, 5.17		65.69	5.14	
III	OH	83.0	138—140	Ether	Crimson	64.52, 64.39	4.74, 4.86		64.62	4.65	

* The yields of acids set forth in Tables 1 and 2 were obtained when rearrangement was performed by method A (see Experimental).

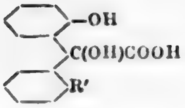
It follows from the data obtained that, as we had expected, monohydroxybenzils (2 and 4) rearrange more rapidly than the corresponding dihydroxybenzils (2,2' and 4,4').* We also see that the rates of rearrangement of 2-hydroxy- and 2,2'-dihydroxybenzils are appreciably higher than the rates of transformation of 4-hydroxy- and 4,4'-dihydroxybenzils, respectively. This unexpected effect of an ortho-substituent can be explained if the benzil rearrangement is regarded as a two-step process [8].



With this mechanism the observed rate of the process depends on the equilibrium constant of the reversible step leading to formation of the intermediate ion (A). It may be suggested that in the case of o-hydroxybenzils, this constant is larger than for p-hydroxybenzils. In the case of o-hydroxy derivatives,the stabilization of ion (A) may be governed by the formation of a hydrogen bond between the hydrogen of the hydroxyl group of that ion and the negatively charged oxygen atom in the ortho position of the benzene nucleus.

* Direct comparison of the rates of rearrangement of 4-hydroxy- and 4,4'-dihydroxybenzils is unnecessary. A clear picture emerges merely from comparison of the conditions and results of experiments 1 and 2.

TABLE 2

Hydroxybenzilic Acids  and Their Derivatives

Acid	R'	Derivative	Yield (in %)	Melting point	Solvent for crystallization
(IV)	H	Acid	94.0	Does not crystallize	—
		Ag salt	—	—	—
		Lactone	Quantitative	103—104°	Benzene, alcohol
		Methyl ester	92.5	109—110	Ether + hexane, benzene
(V)	OCH_3	Acid	96.0	Unsharp (lactonizes on heating)	Water, benzene
		Ag salt	—	—	—
		Lactone	Quantitative	202—203	Alcohol
		Methyl ester	90.0	138.5—139.5	Benzene
(VI)	OH	Acid	92.0	Does not crystallize	—
		Ag salt	—		—
		Lactone	Quantitative	129.5—130.0	Benzene, water
		Methyl ester	88.0	111—112	Benzene

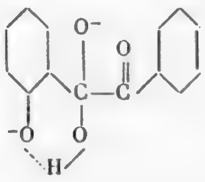
TABLE 3

Comparison of Rates of Rearrangement of Hydroxybenzils

Expt. No.	Hydroxybenzils compared	Concentration of KOH solution and duration of boiling	Yield of acid or corresponding lactone	Hydroxybenzil recovered (in %)
1	2-Hydroxy 4-Hydroxy	15%, 30 min	82.3 34.1	15.0 65.6
2	2,2'-Dihydroxy 4,4'-Dihydroxy	30%, 240 min	85.0 7.3	10.0 92.0
3	2-Hydroxy 2,2'-Dihydroxy	15%, 30 min	84.2 4.0	13.2 94.0

Coloration with conc. H_2SO_4	Found (%)				Calculated (%)			
	C	H	OH	Ag	C	H	OH	Ag
Red, changing to violet	—	—	—	—	—	—	—	—
	—	—	—	30.66, 30.75	—	—	—	30.73
Violet	74.32, 74.36	4.69, 4.66	—	—	74.32	4.46	—	—
Red	70.04, 70.03	5.62, 5.75	12.57, 12.41	—	69.77	5.46	13.17	—
Green	65.92, 66.00	5.38, 5.43	18.62, 18.13	—	65.69	5.14	18.60	—
—	—	—	—	28.15, 28.03	—	—	—	28.30
No color	70.25, 70.33	4.98, 4.88	7.12, 6.90	—	70.33	4.72	6.64	—
Green	66.91, 66.83	5.79, 5.70	—	—	66.65	5.59	—	—
Blue-green	—	—	—	—	—	—	—	—
—	—	—	—	29.39, 29.34	—	—	—	29.39
No color	69.60, 69.07	4.42, 4.34	14.32, 14.41	—	69.40	4.16	14.05	—
Dark green	65.76, 65.75	5.29, 5.27	—	—	65.69	5.14	—	—

The observed effect is more difficult to reconcile with the single-step mechanism of the benzil rearrangement [5,6].



The hydroxy- and dihydroxybenzils used in the present work were prepared by demethylation of the corresponding methoxy- and dimethoxybenzils. We used pyridine hydrochloride as demethylating agent. It proved very convenient and gave excellent yields of hydroxybenzils. In the past these hydroxybenzils were prepared by demethylation in presence of hydrobromic acid or aluminum chloride. The latter reagents generally give lower yields and are very much less convenient, especially when large quantities of substance are being prepared. We made use of hydrobromic acid only for incomplete demethylation of dimethoxybenzils. In Table 4 are presented data for the original methoxy- and dimethoxybenzils and the preparation of hydroxy- and dihydroxybenzils from them. Literature data are included for comparison.

TABLE 4

Methoxy- and Hydroxybenzils

Methoxy-benzils	Melting point found	Melting point literature data	Demethylating agent	Hydroxy-benzils	Yield (in %)	M. p. (recrystallization solvent in brackets)	Literature data: demethylating agent	Literature data: yield (in %)	Literature data: m. p.	Literature data: source
2-Methoxy	72.5—73°	71—72 [9, 10]	$C_5H_5N \cdot HCl$	2-Hydroxy	90	71.5—72° (alcohol + water)	HBr + acetic acid	55.7	74°	[1]
4-Methoxy	61.5—62.5	64—65 [10]	$C_5H_5N \cdot HCl$	4-Hydroxy	96	129.5—130 (benzene)	HBr + acetic acid	Not stated	129—130	[11]
2,2'-Dimethoxy	132—133	128—129 [10]	$C_5H_5N \cdot HCl$	2,2'-Dihydroxy	97	155—156 (benzene)	$AlCl_3$ + benzene or nitrobenzene	50—63	154.5—155.5	[10,12]
			HBr + acetic acid	2-Hydroxy-2'-methoxy	90	125—126 (benzene + hexane or alcohol)	HBr + acetic acid	Not stated	120	[13]
4,4'-Dimethoxy	132.5—133.5	132—133 [10]	$C_5H_5N \cdot HCl$	4,4'-Dihydroxy	98.5	244—246 (alcohol + water)	HBr + acetic acid	87	244—246	[10]
			HBr + acetic acid	4-Hydroxy-4'-methoxy	67.5	162—163 (alcohol + water or benzene)	Lacking			

EXPERIMENTAL

Methoxybenzils

4-Methoxy-, 2,2'- and 4,4'-dimethoxybenzils were prepared from the corresponding benzoins [14-16] by oxidation with copper sulfate in aqueous pyridine [17].

2-Methoxybenzil. To a solution of 44 g of commercial selenious acid in 145 ml of crude dioxane was added 64.8 g of 2-methoxyphenyl benzyl ketone [18]. The solution was boiled for 10 hours, filtered from precipitated selenium and evaporated. The solid product was recrystallized from alcohol. Yield about 80%.

Hydroxybenzils

Complete demethylation of methoxy- and dimethoxybenzils. The starting substance was quickly triturated with double its weight of pyridine hydrochloride. The mixture was put into a flask protected with a calcium chloride tube, and heated for 2 hours at 180° (in the case of 2-methoxy- and 2,2'-dimethoxybenzils) or at 200° (in the case of 4-methoxy- and 4,4'-dimethoxybenzils). The reaction mixture was poured into water, and the product was filtered, dried and recrystallized. If the crude product did not dissolve completely in alkali, it was reprecipitated from the filtered alkaline solution.

Partial demethylation of dimethoxybenzils. 4-Hydroxy-4'-methoxybenzil. 4,4'-Dimethoxybenzil (43 g) was boiled for 2 hours in a mixture of acetic acid (430 ml) and hydrobromic acid (d 1.48) (86 ml). The reaction mixture was then poured into water. The filtered precipitate was treated with dilute aqueous alkali until the hydroxybenzil was fully extracted. The hydroxybenzil was then isolated by acidification. The yield given in Table 4 was calculated with allowance for the unreacted dimethoxybenzil. Careful crystallization from benzene gave 4-hydroxy-4'-methoxybenzil in the form of yellow crystals. Heating above 110-120° or recrystallization from aqueous alcohol yielded a colorless modification which melted at 162-163°.

Found %: C 70.05, 70.12; H 5.02, 4.99. $C_{15}H_{12}O_4$. Calculated %: C 70.33; H 4.72.

2-Hydroxy-2'-methoxybenzil was similarly prepared.

Hydroxybenzilic Acids and Their Derivatives

Two methods of rearrangement were used.

A. Hydroxybenzil (10 g) was charged into a melt of 10 g of potassium hydroxide, 10 g of sodium hydroxide and 7.5 ml of water at 125°. The bath was heated to 150° for 10-15 minutes with continuous stirring and trituration of the mixture by hand. A colorless slurry of the salt of the acid was formed. The salt was dissolved in water, and the solution was carefully neutralized with hydrochloric acid until the yellow color (due to traces of unreacted hydroxybenzil) had disappeared. After filtration, the solution was made acid to congo. The acid was extracted with ether, and the ethereal solution was washed with water and dried with sodium sulfate. The ether was removed without heating during preparation of acids (III-VI).

B. Good yields of acids, except (III), were obtained also by 3-6 hours' boiling of hydroxybenzils in a 5-8-fold molar excess of 20-35% aqueous potassium hydroxide.

Lactones of acids (IV-VI) were prepared by heating of the acids at 80-105° for 2-3 hours. They crystallized on rubbing or on introduction of a seed crystal. Reverse transformation to acid was realized easily by treatment of the lactones with dilute alkali solutions followed by acidification.

Silver salts of acids (IV-VI). Equimolar quantities of lactone or acid and 3.5-5% aqueous potassium hydroxide were heated to the boil. The solution was extracted with ether and heated for removal of the latter. The salt was precipitated with concentrated silver nitrate solution, filtered, washed with a little water, and dried to constant weight.

Methyl esters of acids (IV-VI). A suspension of the silver salt of the acid in dry ether was treated with methyl iodide. The solution was filtered after dilution with acetone; it was then evaporated. The esters crystallized on rubbing or on addition of a seed crystal.

Experiments for Evaluation of Relative Rates of Rearrangement

In each of three experiments, equimolar quantities (0.0041 mole) of a pair of hydroxybenzils were dissolved in identical amounts of aqueous potassium hydroxide: in 30 ml of 15% KOH solution in Expts. 1 and 3 and in 6 ml of 30% KOH solution in Expt. 2. The solutions were refluxed on a glycerol bath whose temperature was kept at 125°. After the boiling, the solutions were diluted with water, and unreacted hydroxybenzils were removed by careful neutralization with hydrochloric acid until the yellow color had disappeared. After filtration and drying to constant weight, the recovered materials were found to be identical with the original substances. The filtrate was made acid to congo and thoroughly extracted with ether; the ether was driven off. Crystalline acids (I and III) were dried to constant weight, but acids (IV and VI) were first lactonized by heating.

SUMMARY

1. The benzil rearrangement of six hydroxy- and dihydroxybenzils was carried out and the corresponding hydroxy- and dihydroxybenzilic acids were obtained. Lactones and methyl esters of some of these acids were prepared.

2. 2-Hydroxy- and 2,2'-dihydroxybenzils were found to rearrange faster than 4-hydroxy- and 4,4'-dihydroxybenzils, respectively. An explanation of this phenomenon was advanced.

3. By using pyridine hydrochloride as demethylating agent it was possible to improve the yields and to effect a more convenient synthesis of some hydroxy- and dihydroxybenzils.

LITERATURE CITED

[1] Y. Asahina and J. Asano, Ber. 62, 171 (1929).

[2] I. A. Pearl, J. Am. Chem. Soc. 76, 3635 (1954).

[3] E. Pfeil, G. Geissler, W. J. Jacquemin, and F. Lömker, Ber. 89, 1210 (1956).

[4] F. L. James and A. L. Ippolito, Ohio J. Sci. 53, 31 (1953).

[5] M. T. Clark, E. C. Hendley, and O. K. Neville, J. Am. Chem. Soc. 77, 3280 (1955).

[6] D. G. Ott and G. G. Smith, J. Am. Chem. Soc. 77, 2325 (1955).

[7] G. G. Smith and D. G. Ott, J. Am. Chem. Soc. 77, 2342 (1955).

[8] I. Roberts and H. C. Urey, J. Am. Chem. Soc. 60, 880 (1938).

[9] K. Brass, E. Willig, and R. Hanssen, Ber. 63, 2613 (1930).

[10] N. J. Leonard, R. T. Rapala, H. L. Herzog, and E. R. Blout, J. Am. Chem. Soc. 71, 2997 (1949).

[11] J. H. Gorvin, Nature 161, 208 (1948).

[12] A. T. Carpenter and R. F. Hunter, J. Appl. Chem. 1, 217 (1951).

[13] A. Schönberg and O. Kraemer, Ber. 55, 1174 (1922).

[14] Organic Reactions [Russian translation] (Moscow, 1951), Pt. IV, p. 229.

[15] J. C. Irvine, J. Chem. Soc. 1901, 668.

[16] J. Sumrell, Y. Stevens, and G. Goheen, J. Org. Chem. 22, 39 (1957).

[17] Organic Syntheses [In Russian] (Moscow, 1949), Vol. I, p. 83.

[18] R. R. Otter and R. L. Shriner, J. Am. Chem. Soc. 73, 887 (1951).

THE MECHANISM OF INTERACTION OF DIBORANE WITH OLEFINS

A. F. Zhigach, V. N. Siryatskaya, I. S. Antonov,

and S. Z. Makaeva

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 227-230, January, 1960

Original article submitted January 24, 1959

According to the literature, the reaction of diborane with various olefins at temperatures of 0 to 100° proceeds with high velocity with formation of highly polymeric products containing boron, carbon and hydrogen [1].

Careful performance of the reaction (gradual heating, definite ratio of reactants) leads to addition of diborane at the carbon – carbon double bond with formation of trialkyl derivatives of boron [2].

A proposed mechanism of the process of interaction of diborane with excess of olefins, based on data for reaction of diborane with ethylene [3], involves successive formation of alkyldiboranes [RB_2H_5 (I), $R_2B_2H_4$ (II), $R_3B_2H_3$ (III), etc.] according to the equations:

$$B_2H_6 \rightleftarrows 2BH_3 \text{ (IV)},$$
$$B_2H_6 + BH_3 \longrightarrow B_3H_9 \text{ (V)},$$
$$B_3H_9 + C_nH_{2n} \longrightarrow BH_3 + B_2H_5C_nH_{2n+1} \text{ (VI)},$$
$$B_2H_5C_nH_{2n+1} + BH_3 \longrightarrow B_3H_8C_nH_{2n+1} \text{ (VII)},$$
$$B_3H_8C_nH_{2n+1} + C_nH_{2n} \rightarrow BH_3 + B_2H_4(C_nH_{2n+1})_2 \text{ (VIII)},$$
$$B_3H_4(C_nH_{2n+1})_5 + C_nH_{2n} \longrightarrow BH_3 + 2B(C_nH_{2n+1})_3 \text{ (IX)}$$

In theory a boron atom can add on to any of the carbon atoms at the double bond, and we should therefore expect formation of two isomers during the reaction. Hurd [1, 2] reports the formation of equal quantities of two isomeric organoboron compounds, for example:

$$B_2H_6 + 6 \begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>\!C{=}CH_2 \longrightarrow 2B\left(\begin{matrix} CH_3 \\ CH_3 \\ CH_3 \end{matrix}\!\!>\!C\right)_3 \quad \text{(X)}$$

$$B_2H_6 + 6 \begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>\!C{=}CH_2 \longrightarrow 2B\left(\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>\!CH{-}CH_2\right)_3 \quad \text{(XI)}$$

According to Eq. (X) the addition follows the Markovnikov rule and the reaction product is tritert-butylboron. According to Eq. (XI) a hydrogen atom adds on to the less hydrogenated carbon atom, and the reaction product is triisobutylboron.

Other workers, however, point out [4, 5] that the corresponding primary alcohols are obtained when organoboron compounds are synthesized by reduction of olefins with sodium borohydride in presence of aluminum chloride.

In view of the conflicting reports in the literature about the sequence of addition of diborane to olefins, we investigated the mechanism of these additions. We prepared tripropyl-, tributyl- and triisobutylborons. The structure of the resulting alkylborons was established with the help of oxidation and hydrolysis to the corresponding alcohols and boric acid according to the equation [6]:

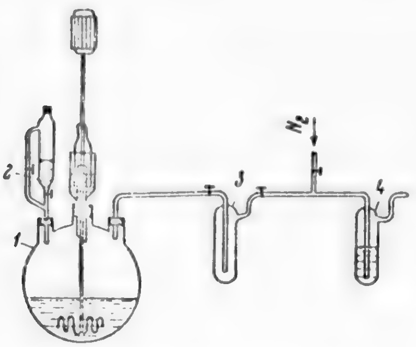
$$B(C_nH_{2n+1})_3 + 3H_2O_2 + KOH \longrightarrow KBO_2 + 3C_nH_{2n+1}OH + 2H_2O. \quad (XII)$$

The alcohols were isolated and examined. In all cases, it was found that the main products of oxidation and hydrolysis of the alkylborons are primary alcohols. Direct proof was thereby obtained of the addition of diborane to the double carbon – carbon bond according to Eq. (XI), i.e., contrary to the Markovnikov rule. According to Scheme (X) the reaction products should have been tertiary alcohols in the case of interaction of diborane with isobutene, and secondary alcohols in the case of interaction of diborane with propylene.

EXPERIMENTAL

Preparation of Alkylborons

All experiments were performed with diborane which had been carefully purified (diborane content over 99%). Olefins were prepared by catalytic dehydration of the alcohols over alumina at 350-360°. The alcohols were rectified beforehand and fractions boiling within a 2° range were collected. The gaseous olefins were passed through drying towers filled with calcium chloride. The olefin content of each sample was not less than 98%. Reactions were carried out in a nitrogen atmosphere with exclusion of air and moisture.



Apparatus for oxidation of organoboron compounds. Explanation in text.

Preparation of tripropylboron. This was performed in a circulating system. The diborane concentration of the diborane – propylene gas mixture was 3.5-3.8%. The temperature in the reaction zone was 230-250°. Under these conditions diborane entered into reaction quantitatively. From 1.4 g of diborane was obtained 14.1 g of tripropylboron (yield of over 99% on the diborane). The crude tripropylboron contained 7.8% of boron. A small quantity of propyldiboranes was detected as impurity. Rectification in vacuo at a residual pressure of 20 mm and 59-60° yielded 12.9 g (91%) of pure tripropylboron.

Found %: B 7.70; C 76.98; H 14.90. $C_9H_{21}B$. Calculated %: B 7.74; C 77.24; H 15.02.

Preparation of triisobutylboron. The same procedure was employed. From 1.6 g of diborane was obtained 20.9 g (over 99%) of crude triisobutylboron. Rectification in vacuo at a residual pressure of 20 mm and 85-86° gave 19.3 g (92%) of pure triisobutylboron.

Found %: B 6.0; C 79.10; H 14.90. $C_{12}H_{27}B$. Calculated %: B 5.94; C 79.12; H 14.90.

Tributylboron was similarly prepared. From 1.3 g of diborane was obtained 17 g of crude tributylboron. Yield (on diborane) 99%. Rectification of the crude product in vacuo at a residual pressure of 9 mm and 89-90° gave 16 g (94%) of pure tributylboron.

Found %: B 5.98; C 79.02; H 14.80. $C_{12}H_{27}B$. Calculated %: B 5.94; C 79.12; H 14.90.

Oxidation of Organoboron Compounds

Oxidation of tripropylboron. The reaction was carried out in the apparatus sketched in the diagram. Into reaction vessel 1, fitted with dropping funnel 2 and a stirrer, were charged 34 g of tripropylboron and 40 g of 50% potassium hydroxide solution. Into this mixture was gradually stirred (from the dropping funnel) 22 g of 40% hydrogen peroxide. Any entrained fine particles of liquid products were deposited in bottle 3 or decomposed in vessel 4. The temperature of the reaction mixture did not exceed 20°. On completion of the reaction (in 3.5 hours) the aqueous alcoholic layer was separated and 42 g of crude alcohol (95%) was distilled off from it. The

crude alcohol was carefully dehydrated by heating over calcined copper sulfate. The dehydrated alcohol was rectified at atmospheric pressure and the 95.5-97.5° fraction was collected. The boiling point is the same as that of n-propyl alcohol.

Oxidation of triisobutylboron. From 30 g of triisobutylboron was obtained 35 g (95%) of isobutyl alcohol. After thorough dehydration over calcined copper sulfate, the product was rectified to give an alcohol with b. p. 106.5-108°. The boiling point was the same as that of isobutyl alcohol.

Oxidation of tributylboron. Oxidation of 32 g of tributylboron gave 37.5 g (96%) of butyl alcohol. Thorough dehydration, followed by rectification, gave an alcohol boiling at 115.5-117°. The boiling point is that of n-butyl alcohol. Data for the isolated alcohols are set forth in the table.

Properties of the Alcohols

Alcohol	Boiling point		n_D^{20}		d^{20}_4		Found (%)		Calculated (%)	
	found	lit. data [7]	found	lit. data [8]	found	lit. data [7]	C	H	C	H
n-Propyl	95.5—97.5°	97.2°	1.385	1.385	0.803	0.803	59.84	13.51	59.96	13.42
Isobutyl	106.5—108	108.1	1.395	1.395	0.802	0.802	64.78	13.68	64.82	13.66
n-Butyl	115.5—117	117	1.399	1.399	0.809	0.809	64.71	13.65	64.82	13.66

SUMMARY

1. The following alkylborons were prepared by reaction of diborane with olefins: tripropyl-, tributyl and triisobutylborons.

2. Oxidation of alkylborons with hydrogen peroxide in presence of potassium hydroxide was studied. Oxidation of tripropylboron gives n-propyl alcohol, oxidation of tributylboron gives n-butyl alcohol, and oxidation of triisobutylboron gives isobutyl alcohol.

3. It was established that reaction of diborane with olefins results in addition of boron at the primary carbon atom.

LITERATURE CITED

[1] D. Hurd, J. Am. Chem. Soc. 70, 2053 (1948).

[2] D. Hurd, Introduction to the Chemistry of Hydrides [Russian translation] (IL, 1935).

[3] A. Whatley and R. Pease, J. Am. Chem. Soc. 76, 835 (1954).

[4] H. Brown and B. Subba, J. Am. Chem. Soc. 78, 5694 (1956).

[5] Chem. Eng. News 6, 28 (1957).

[6] H. Shyder, J. Kuck, and J. Johnson, J. Am. Chem. Soc. 60, 121 (1938).

[7] A. E. Chichibabin, Principles of Organic Chemistry [In Russian] (State Chem. Press, 1953), I.

[8] Handbook of Chemistry [In Russian] (1957), II.

DEMETHYLATION OF TOLUENE AND XYLENE UNDER DESTRUCTIVE HYDROGENATION CONDITIONS

D. M. Maiorov

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 230-232, January, 1960

Original article submitted November 16, 1958

Demethylation of toluene or xylene under destructive hydrogenation conditions is an interesting possibility of production of benzene apart from the usual methods based on coking of coal and dehydrogenation of cyclohexane. Toluene and xylene can be produced on a considerable scale by present-day methods of petroleum processing. Demethylation of toluene in presence of hydrogen was carried out by F. Fischer in a tinned iron tube at 750° [1]. Hofman and Lang also realized this reaction without a catalyst but at an initial hydrogen pressure of 70 atm and a temperature of 460° [2]. According to Laidler and Szayna, the hydrogenation of toluene in presence of molybdenum sulfate at 490° for 1 hour leads to formation of 25% of benzene [3]. P. V. Puchkov and A. F. Nikolaeva point out that they did not find benzene among the reaction products after hydrogenation of toluene in presence of molybdenum disulfide at 400°, but that the crude product contained 12.4% of benzene at 470° under otherwise identical conditions [4]. B. L. Moldavskii and L. S. Bezdel' effected the dealkylation of 14 alkylbenzenes over an activated natural aluminosilicate (gumbrine) at 410° without introduction of hydrogen into the reaction zone [5]. The yield of benzene from the majority of these hydrocarbons was insignificant, and only in one case (isobutylbenzene) did it reach 67%. Silsby and Sawyer [6] carried out experiments on demethylation of toluene and xylenes at various temperatures and pressures of hydrogen and derived a series of kinetic relations.

As far as we know, nobody has yet undertaken a thermodynamic analysis of demethylations of methylbenzenes in presence of hydrogen. In the present work we calculate the yields of benzene in dependence on temperature for the reactions:

$$C_6H_5CH_3 + H_2 \rightleftarrows C_6H_6 + CH_4, \qquad (I)$$

$$C_6H_4(CH_3)_2 + 2H_2 \rightleftarrows C_6H_6 + 2CH_4. \qquad (II)$$

Since these reactions proceed without volume change, the pressure cannot upset the equilibrium position. The necessity for application of high hydrogen pressure for demethylation of toluene or xylene can only arise in connection with the safeguarding of the catalyst against coke deposition (i.e., avoidance of far-reaching decomposition which may occur at high temperature).

Hydrogenation of the benzene ring to the cyclohexane ring and subsequent decomposition of the latter to products of low value are not considered here. The thermodynamic values for the above-noted hydrocarbons and hydrogen are taken from A. A. Vvedenskii's monograph [7]. p-Xylene was used in the calculation of reaction (II).

It is known that the dependence of the equilibrium constant on the thermal effect of a reaction is expressed by the equations:

$$\lg K_p = -\frac{\Delta H_0}{4.573 \cdot T} + \frac{\Delta \Gamma_0}{1.986} \lg T + \frac{\Delta \Gamma_1}{2 \cdot 4.573} T + \frac{\Delta \Gamma_2}{6 \cdot 4.573} T^2 + \ldots - \frac{I}{4.573}, \quad \text{(III)}$$

$$\Delta H = \Delta H_0 + \Delta \Gamma_0 T + \frac{\Delta \Gamma_1}{2} T^2 + \frac{1}{3} \Delta \Gamma_2 T^3 + \ldots \quad \text{(IV)}$$

The coefficients $\Delta\Gamma_0$, $\Delta\Gamma_1$, and $\Delta\Gamma_2$ are found from the equations relating the heat capacities of hydrocarbons and hydrogen to the temperature [7].

For reaction (I) $\Delta\Gamma_0 = -3.64$, $\Delta\Gamma_1 = -0.0036$, $\Delta\Gamma_2 = 0.0000008$. For reaction (II), $\Delta\Gamma_0 = -7.72$, $\Delta\Gamma_1 = 0.00408$, $\Delta\Gamma_2 = 0.0000009$.

From the heats of combustion and heats of formation of the substances participating in reactions (I) and (II), we find the thermal effects of the reactions at 298° K, which have the values of − 10015 for reaction (I) and − 20241 kcal/mole for reaction (II).

Inserting the values found in Eqs. (III) and (IV) and rearranging, we obtain:

$$\lg K_{p_I} = \frac{1919}{T} - 1.833 \lg T - 0.000393\, T + 0.000000029\, T^2 + 5.823 \quad \text{(V)}$$

$$\lg K_{p_{II}} = \frac{3965}{T} - 3.887 \lg T + 0.000446\, T + 0.0000000328\, T^2 + 12.688. \quad \text{(VI)}$$

Values of equilibrium constants calculated from these equations for various temperatures are set forth in the table. We see that the equilibrium constants decrease with rising temperatures; the equilibrium constants of reaction (II) are larger than those of reaction (I) by several powers of ten.

Numerical Values of Equilibrium Constants Calculated from Eqs. (V) and (VI)

T°K	$\lg K_{p_I}$	K_{p_I}	$\lg K_{p_{II}}$	$K_{p_{II}}$
300	7.564	$36.65 \cdot 10^6$	16.409	$25.64 \cdot 10^{15}$
400	5.699	$50.01 \cdot 10^4$	12.699	$50.00 \cdot 10^{11}$
500	4.525	$33.50 \cdot 10^3$	10.362	$23.02 \cdot 10^9$
600	3.703	$50.47 \cdot 10^2$	8.778	$59.98 \cdot 10^7$
700	3.088	$12.25 \cdot 10^2$	7.618	$41.50 \cdot 10^6$
800	2.605	$40.28 \cdot 10$	6.738	$54.70 \cdot 10^5$
900	2.209	$16.19 \cdot 10$	6.038	$10.92 \cdot 10^5$
1000	1.879	$7.57 \cdot 10$	5.471	$29.60 \cdot 10^4$

For reaction (I) let each mole of equilibrium mixture at temperature T contain x moles of benzene; let the corresponding number of reaction (II) be y. From the terms of the problem, $x \le 1/2$ and $y \le 1/3$; hence

$$K_{p_I} = \frac{4x^2}{1 - 4x + 4x^2} \quad \text{(VII)}$$

$$K_{p_{II}} = \frac{27y^3}{1 - 9y + 27y^2 - 27y^3} \quad \text{(VIII)}$$

After rearrangement, we have

$$4\left(K_{p_I}-1\right)x^2-4K_{p_I}x+K_{p_I}=0 \quad \text{(IX)}$$

$$27\left(K_{p_{II}}+1\right)y^3-27K_{p_{II}}y^2+9K_{p_{II}}y-K_{p_{II}}=0 \quad \text{(X)}$$

When $K_p \gg 1$, Eqs. (IX) and (X) transform to the equations

$$x^2-x+\frac{1}{4}=0 \quad \text{(XI)}$$

$$y^3-y^2+\frac{1}{3}y-\frac{1}{27}=0, \quad \text{(XII)}$$

and hence $x = {}^1/_2$ and $y = {}^1/_3$.

Since the magnitudes of K_{p_I} and $K_{p_{II}}$ in the 300-1000° K temperature range considerably exceed unity, we can conclude that the equilibrium of reactions (I) and (II) is completely shifted in the direction of formation of benzene and methane.

SUMMARY

Demethylation of toluene and xylenes under destructive hydrogenation conditions can be carried out in a wide range of temperatures. The practical realization of the reaction calls for a catalyst in whose presence the reaction will proceed with adequate speeds.

LITERATURE CITED

[1] F. Fischer and H. Schrader, Brennst. Chem. 1, 5, 22 (1920).

[2] F. Hofman and K. Lang, Brennst. Chem. 10, 203 (1929).

[3] K. Laidler and A. Szayna, J. Inst. Petr. Techn. 20, 162 (1934).

[4] P. V. Puchkov and A. F. Nikolaeva, Zhur. Obshchei Khim. 8, 1756 (1938).

[5] B. L. Moldavskii and L. S. Bezdel', Zhur. Obshchei Khim. 16, 1633 (1946).

[6] K. I. Silsby and E. W. Sawyer, J. Appl. Chem. 8, 8, 347 (1956).

[7] A. A. Vvedenskii, Thermodynamic Calculations of the Fuel Industry [In Russian] (GNTI Petroleum and Fuel Literature, 1949).

THE INTERACTION OF GLYCIDOL WITH ORGANOCHLOROSILANES

M. K. Romantsevich and M. S. Malinovskii

Lvov Zooveterinary Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 232-234, January, 1960

Original article submitted November 15, 1958

Previously [1] we investigated the interaction of ethylene oxide, propylene oxide, epichlorohydrin, glycide methyl ester, cyclohexene oxide and styrene oxide with organochlorosilanes. Special attention was paid in these investigations to the sequence of opening of the oxide ring of unsymmetrical α-oxides.

The purpose of the present work was the study of the interaction of glycidol with organochlorosilanes. The literature on this problem [2] indicates that glycidol reacts with R_nSiCl_{4-n} according to the equation

$$R_nSiCl_{4-n} + (4-n)\ \underset{\diagdown O \diagup}{H_2C{-}CHCH_2OH} \longrightarrow R_nSi(OCH_2CHClCH_2OH)_{4-n}. \quad (1)$$

The structures of the resulting compounds and the sequence of rupture of the oxide ring of glycidol had not been established.

It seemed to us that glycidol in its reactions with organochlorosilanes would behave similarly to epichlorohydrin and glycide methyl ether with rupture of the oxide ring on the side of the less hydrogenated carbon atom:

$$R_nSiCl_{4-n} + (4-n)\ \underset{\diagdown O \diagup}{H_2C{-}CHCH_2OH} \longrightarrow R_nSi\left(OCH\begin{matrix} \diagup CH_2Cl \\ \diagdown CH_2OH \end{matrix}\right)_{4-n} \quad (2)$$

In order to clarify this point, we studied the reaction of glycidol with the following organochlorosilanes: CH_3SiCl_3, $(CH_3)_2SiCl_2$, $(CH_3)_3SiCl$ and CH_3SiHCl_2. Formulas and some properties of the compounds obtained are set forth in the table.

The structure of the prepared compounds was confirmed by their hydrolysis, followed by reduction of the products of hydrolysis with sodium amalgam [3]. In all cases α-propylene glycol was obtained in good yield. This could only have been formed from the products of reaction (2) according to the following scheme

$$R_nSi\left(OCH\begin{matrix} \diagup CH_2Cl \\ \diagdown CH_2OH \end{matrix}\right)_{4-n} + (4-n)\,H_2O \longrightarrow$$

$$R_nSi(OH)_{4-n} + (4-n)\,ClCH_2CHOHCH_2OH$$

$$ClCH_2CHOHCH_2OH \xrightarrow{H_2} CH_3CHOHCH_2OH$$

Formula	Yield (in %)	B. p. (pressure in mm)	n_D^{20}	d_4^{20}	MR_D found	MR_D calc.	% Cl found	% Cl calc.	% Si found	% Si calc.
$(CH_3)_3SiOCH<^{CH_2Cl}_{CH_2OH}$	82.7	82.5—83° (13)	1.4342	1.0096	47.15	46.69	19.51, 19.34	19.40	15.24, 15.31	15.37
$(CH_3)_2Si\left(OCH<^{CH_2Cl}_{CH_2OH}\right)_2$	59.4	96—97 (4)	1.4734	1.2365	62.94	63.10	25.34, 25.50	25.58	9.97, 10.05	10.13
$CH_3Si\left(OCH<^{CH_2Cl}_{CH_2OH}\right)_3$	36.5	132—133 (3)	1.4840	1.3327	79.80	79.51	28.77, 28.52	28.62	7.48, 7.64	7.56

Glycidol differs from the α-oxides that we previously studied in containing two reactive groups. Notwithstanding that the α-oxide ring has a far greater reactivity than the alcohol group, the latter still has considerable activity, especially in reactions with organochlorosilanes containing two or more chlorine atoms. Evidence of this is the formation of large quantities of high-molecular products (still residues). It should be noted that the products of reaction of glycidol with organochlorosilanes are not thermally or hydrolytically stable (in particular the product of reaction of glycidol with CH_3SiHCl_2, which could not be fractionated).

EXPERIMENTAL

Preparation of di-(α-chloro-γ-hydroxyisopropoxy)-dimethylsilane. A four-necked flask was fitted with a mechanical stirrer passing through a reflux condenser, two dropping funnels and a thermometer. From the two dropping funnels were gradually introduced (simultaneously) glycidol (30.5 g) and dimethyldichlorosilane (25.8 g). The glycidol was added at such a rate that it was always present in slight excess in the flask and the temperature did not exceed 30°. The reaction mixture was thereupon heated for 4 hours at 50-60°, and the reaction products were fractionated in vacuo. At 96-97° (4 mm) was collected 32.9 g (59.4%) of di-(α-chloro-γ-hydroxyisopropoxy)-dimethylsilane whose constants are set forth in the table.

The same procedure was followed for the other syntheses.

Hydrolysis of di-(α-chloro-γ-hydroxyisopropoxy)-dimethylsilane and reduction of the products of hydrolysis. The starting substance (20 g) was put into a three-necked flask fitted with mechanical stirrer, dropping funnel and thermometer. Water (10 ml) to which had been added concentrated HCl (0.7 ml) was added from the dropping funnel. Addition of the acidified water to the stirred liquid caused the temperature to rise slightly (30-35°). After 4 hours' stirring,followed by overnight standing, two liquid layers formed. The upper, oily layer was collected and the aqueous layer was fractionated. Distillation of the water was followed by collection of a substance whose properties were very similar to those of glycerol α-chlorohydrin. The structure of the latter was confirmed by reduction with sodium amalgam while shaking for three days. From the reduction products was isolated 6 g of a colorless and odorless liquid with a sweet taste; b. p. 188°, $n^{20}D$ 1.4321, d^{20}_4 1.0387, MR_D 19.01. Its properties corresponded to those of α-propylene glycol.

Literature data for α-propylene glycol [4]: b. p. 188.2°, 188-189°, $n^{25}D$ 1.432, d^{20}_4 1.038, $d^{19.5}$ 1.040; MR_D 19.12.

SUMMARY

1. Condensation of organochlorosilanes with glycidol is accompanied by rupture of the oxide ring on the side of the secondary carbon atom.

2. Three α-chloro-γ-hydroxyisopropoxyorganosilanes were prepared and characterized; another structure had been assigned to them in the literature.

LITERATURE CITED

[1] M. F. Shostakovskii, M. S. Malinovskii, M. K. Romantsevich, and D. A. Kochkin, Izvestiya Akad. Nauk SSSR, Otdel. Khim. Nauk 1956, 632;* M. S. Malinovskii and M. K. Romantsevich, Zhur. Obshchei Khim. 27, 1680, 1873 (1957).*

[2] K. A. Andrianov, P. N. Sokolov, E. N. Khrustaleva, and L. N. Yukina, Izvestiya Akad. Nauk SSSR, Otdel. Khim. Nauk 1955, 531.*

[3] A. Lourenco, Lieb. Ann. 120, 91 (1861).

[4] Chemical Reagents and Preparations (Handbook) [In Russian] (State Chem. Press, 1953), p. 456; Handbook of Chemistry [In Russian] (State Chem Press, 1951), II, p. 710.

* Original Russian pagination. See C. B. translation.

THE PROBLEM OF THERMAL BREAKDOWN OF ORGANOSILICON COMPOUNDS

D. A. Petrov, G. T. Danilova-Dobryakova, and V. F. Trokhova

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 235-239, January, 1960

Original article submitted December 27, 1958

Many methods of preparation of pure metals are described in the literature. Thermal decomposition of iodides, bromides and chlorides is widely practiced for this purpose. Preparation of pure aluminum by decomposition of organometallic compounds was recently reported [1]. We thought fit to apply the method of thermal decomposition to organosilicon compounds with the objective of preparation of pure silicon.

Syntheses of organosilicon compounds have been worked out in fair detail, and there are a large number of investigations in this field [2-8]. Little work has been published on the composition of the products of breakdown of these compounds [9-11]. On the basis of Waring's data [9] we may put forward the following scheme for thermal breakdown of tetraethylsilane.

$$\begin{gathered}
Si(C_2H_5)_4 \longrightarrow Si + 4C_2H_5\cdot,\\
Si(C_2H_5)_4 \longrightarrow \cdot Si(C_2H_5)_3 + \cdot C_2H_5 \quad \text{(slow)},\\
\cdot Si(C_2H_5)_3 \longrightarrow Si + 3C_2H_5\cdot \quad \text{(slow)},\\
\cdot C_2H_5 \longrightarrow C_2H_4 + H,\\
2H \longrightarrow H_2 \quad \text{(fast)},\\
C_2H_4 \longrightarrow CH_4 + C \quad \text{(slow)}.
\end{gathered}$$

This scheme postulates several steps leading to silicon, carbon, hydrogen and hydrocarbons as end-products.

It was established that the most stable hydrocarbon during pyrolysis of organosilicon compounds is methane, whose formation is always associated with deposition of carbon [9-11].

EXPERIMENTAL

Starting substances were substituted silanes, alkylhalosilanes and substituted ethers. Eleven organosilicon compounds in all were examined.

The synthesized compounds were repeatedly distilled, a middle cut being collected in each case. The investigated compounds are listed and their physical properties set forth in Table 1.

Thermal decomposition of the organosilicon compounds was carried out in the apparatus sketched in Fig. 1. It comprised a quartz reaction tube 1 (inside diameter 26 mm), a quartz vaporizer 2, a vacuum funnel 3 and a trap 4 (cooled with liquid nitrogen). All parts were joined by ground-glass fittings 5. The organosilicon compounds were pyrolyzed at the walls of the reaction tube and in isolated cases on tantalum sheet located in the reaction tube. The pressure in the system was measured by a mercury gauge 7. At the end of the reaction tube was a No. 16 quartz filter which lowered the flow rate of the compound and prevented solid products of breakdown from being carried out of the tube. Pyrolysis was performed at temperatures of 300 to 1200° and a residual

pressure of 50-80 mm; the rate of vaporization of the substances was 0.03-0.04 ml/sec. The reaction tube was inserted in a tube furnace, and temperatures were measured at three points. The temperature gradient along the length of the reaction tube did not exceed 20-30°.

TABLE 1

Physical Properties of Starting Substances

Compd. No.	Names and formulas of compounds	B. p.	d_4^{20}	n_D^{20}
1	Tetramethylsilane $(CH_3)_4Si$ [2–4, 9]	26.5°	0.645	1.3478
2	Tetraethylsilane $(C_2H_5)_4Si$ [2, 4, 9]	151–153	0.7662	1.424
3	Methyldiethylsilane $CH_3(C_2H_5)_2SiH$	70	—	—
4	Methyldibutylsilane $CH_3(C_4H_9)_2SiH$	52–54 (8mm)	—	—
5	Triethylphenylsilane $(C_2H_5)_3C_6H_5Si$ [2, 5]	236	0.906 (0°)	—
6	Allylmethylphenylsilane $\begin{matrix} CH_2{=}CH{-}CH_2 \\ C_6H_5 \end{matrix}\!\!>\!SiHCH_3$	77.9	0.8755	1.4934
7	Dimethylethylphenylsilane $(CH_3)_2Si(C_2H_5)C_6H_5$ [2, 6]	197–199	0.881	—
8	Methyldichlorosilane CH_3SiHCl_2 [2, 7]	46.6	1.105	—
9	Ethyldichlorosilane $C_2H_5SiHCl_2$ [2, 8]	74.9	—	—
10	Dimethyldiethoxysilane $(CH_3)_2Si(OC_2H_5)_2$ [2]	111–114	0.890	1.3839 (25°)
11	Phenylmethyldiethoxysilane $C_6H_5(CH_3)Si(OC_2H_5)_2$ [2]	221.5	—	—

Note. Compounds 3, 5 and 6-9 were provided by V. F. Mironov, compounds 10 and 11 by K. A. Andrianov.

TABLE 2

Content of Carbon in Starting Substances and in Their Pyrolysis Products

Compounds investigated	Initial temp. of pyrolysis	Carbon content (in %)				
		in original comp.	in solid breakdown products obtained at pyrolysis temperature			
			600°	800°	1000°	1200°
$(CH_3)_4Si$	660°*	54	25.3	27.3	28.3	—
$(C_2H_5)_4Si$	580*	66.7	20.5	22.6	30.0	31.4
$CH_3(C_2H_5)_2SiH$	600	58.8	23.8	25.5	26.7	—
$CH_3(C_4H_9)_2SiH$	1000	68.3	Does not decomp.	Does not decomp.	10.3	19
$(C_2H_5)_3C_6H_5Si$	800	75	Ditto	25.3	—	—
$CH_2{=}CH{-}CH_2(CH_3)(C_6H_5)SiH$	800	74	» »	23.5	23.6	—
$(CH_3)_2Si(C_2H_5)C_6H_5$	800	73	» »	27.3	28	—
CH_3SiHCl_2	800	10.4	» »	22.5	25.3	—
$C_2H_5SiHCl_2$	800	18.6	» »	23.5	27.5	—
$(CH_3)_2Si(OC_2H_5)_2$	600	48.6	28.3	31	36.6	39.7
$C_6H_5(CH_3)Si(OC_2H_5)_2$	800	62.7	Does not decomp.	28.4	42	46

* According to the literature.

The content of carbon and solid products of decomposition was determined by the combustion method. Substances present in traces were determined spectroscopically. We did not analyze the gaseous products.

The procedure was as follows: The system was evacuated to a residual pressure of 10^{-2} mm, and at the same time the heating of the reaction tube was commenced. After the required temperature had been reached, purified argon was passed 2-3 times through the apparatus, and then the admission of the starting substance through the vacuum funnel and into the vaporizer was started (the vaporizer was immersed in a water bath). The rate of vaporization was regulated by altering the water-bath temperature.

Results are presented in Tables 2 to 5.

TABLE 3

Distribution of Carbon Along the Tube in Solid Products of Breakdown of $C_6H_5(CH_3)Si(OC_2H_5)_2$

Pyrolysis temperature	Carbon content of breakdown products at various zones of reaction tube (in %)		
	start	middle	end
800°	25.3	38.4	40.3
1000	38.5	40.0	43.3

TABLE 4

Content of Impurities in Starting Compounds and in Solid Breakdown Products (Pyrolysis Temperature 800°)

Starting compound	Content of impurities (in %)						
	Mg	Al	Fe	Mn	Cu	Ca	Na
$(C_2H_5)_4Si$	$\frac{10^{-2}}{10^{-3}}$	$\frac{10^{-4}}{10^{-4}}$	$\frac{10^{-4}}{10^{-4}}$	$\frac{10^{-3}}{—}$	$\frac{10^{-3}—10^{-4}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}}{10^{-3}—10^{-4}}$	$\frac{10^{-2}}{—}$
$(CH_3)_2Si(OC_2H_5)_2$	$\frac{10^{-3}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}—10^{-4}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}—10^{-4}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}}{—}$	$\frac{10^{-3}—10^{-4}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}}{—}$	$\frac{10^{-3}}{—}$
CH_3SiHCl_2	$\frac{10^{-3}}{10^{-3}}$	$\frac{10^{-3}—10^{-4}}{10^{-4}}$	$\frac{10^{-3}—10^{-4}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}}{—}$	$\frac{10^{-3}—10^{-4}}{10^{-4}}$	$\frac{10^{-2}}{—}$	$\frac{10^{-3}}{10^{-3}}$
$C_6H_5(CH_3)Si(OC_2H_5)_2$	$\frac{10^{-3}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}—10^{-4}}{10^{-3}—10^{-4}}$	$\frac{10^{-3}—10^{-4}}{10^{-4}}$	$\frac{10^{-3}}{10^{-4}}$	$\frac{10^{-3}—10^{-4}}{10^{-4}}$	$\frac{10^{-3}—10^{-4}}{—}$	$\frac{10^{-3}}{—}$

Note. In the column "content of impurities" the numerator relates to data for the starting compound and the denominator to data for the solid product of its pyrolysis.

DISCUSSION OF RESULTS

Initial temperatures of thermal breakdown of $(CH_3)_4Si$ and $(C_2H_5)_4Si$ have been reported in [7-9]; we roughly determined the values for the remaining compounds, taking the temperature of commencement of deposition of silicon and carbon on the walls of the reaction tube as the initial temperature of far-reaching pyrolysis.

According to the data of Table 2, the investigated organosilicon compounds do not start to undergo far-reaching pyrolysis until 600-1000° is reached. The solid products of pyrolysis differed in form and color. The product deposited on tantalum sheet was in the form of scales with a metallic luster; on a quartz surface the products were finely dispersed powders or dense granules whose color varied from gray (at low temperatures) to black (at high temperatures).

Data characterizing the content of carbon in the solid products of breakdown are presented in Table 2. They indicate that the silicon obtained in all experiments contained a high proportion of carbon (an average of 25% of the weight of the solid products of breakdown). The smallest carbon content (10-20%) was present in the silicon resulting from breakdown of $(C_2H_5)_4Si$ and $CH_3(C_4H_9)_2SiH$. The highest carbon content (about 40%) was present in silicon resulting from decomposition of substituted ethers, namely $(CH_3)_2Si(OC_2H_5)_2$ and $C_6H_5(CH_3)Si(OC_2H_5)_2$. It should be noted that the carbon content of the solid products is by no means proportional to the carbon content of the starting compounds.

TABLE 5

Content of Impurities in Solid Products of Breakdown of Tetraethylsilane at Various Pyrolysis Temperatures

Pyrolysis temp.	Content of impurities (in %)				
	Mg	Al	Fe	Cu	Ca
600°	10^{-3}	10^{-4}	10^{-4}	10^{-3}—10^{-4}	10^{-3}—10^{-4}
800	10^{-3}	10^{-4}	10^{-4}	10^{-3}—10^{-4}	10^{-3}—10^{-4}
1000	10^{-3}	10^{-3}	10^{-4}	10^{-4}	10^{-3}—10^{-4}
1200	10^{-3}	10^{-3}	10^{-4}	10^{-4}	10^{-3}—10^{-4}

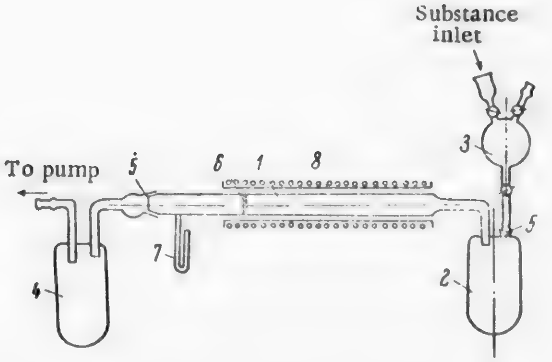


Fig. 1. Line diagram of apparatus for pyrolysis of organosilicon compounds. Details in text.

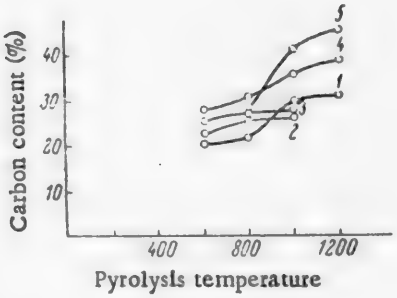


Fig. 2. Carbon content of solid products of breakdown at various temperatures of pyrolysis of organosilicon compounds. 1) $(C_2H_5)_4Si$; 2) $(CH_3)(C_2H_5)_2SiH$; 3) $(CH_3)_4Si$; 4) $(CH_3)_2Si(OC_2H_5)_2$; 5) $C_6H_5(CH_3)Si(OC_2H_5)_2$.

The carbon content of breakdown products from five compounds is plotted as a function of the temperature in Fig. 2. It follows from the data that in the investigated temperature range, the carbon content of the breakdown products increases with rising pyrolysis temperature.

The carbon content varies to an insignificant extent at different parts of the reaction tube (Table 3).

Results of spectral analysis of the starting substances and of their breakdown products are set forth in Table 4. They permit the conclusion that starting compounds and solid products of their pyrolysis do not differ appreciably in respect to their content of the impurities Mg, Al, Fe and Cu. Judging by the data of Table 5, change of pyrolysis temperature in the 600-1200° range also does not influence the content of these impurities in the products of decomposition.

It should be noted that the impurities are not uniformly distributed along the length of the reaction tube. The content of Al, Fe, and Mg tends to be greater in the middle of the reaction tube. Finally, we may note that destructive breakdown of organosilicon compounds leads ultimately to a very much higher content of silicon than of carbon. The authors convey their profound thanks to K. A. Andrianov, A. I. Zakharkina, V. F. Mironov, and O. Yu. Okhlobystina for their assistance in the work.

SUMMARY

1. Far-reaching pyrolysis of organosilicon compounds in the 300-1200° range was studied. Silicon and carbon (10-40%) were always found among the solid products of breakdown.

2. The carbon content of the breakdown products increases with rising temperature.

3. The carbon content of the breakdown products is independent of its content in the starting compounds.

4. Impurities present in the original compounds pass over in their entirety, except for the Mn and Na, into the solid breakdown products.

5. Initial temperatures of pyrolysis of nine organosilicon compounds were roughly determined.

LITERATURE CITED

[1] K. Ziegler and H. Gellert, Ang. Chem. 67, 424 (1955).

[2] K. A. Andrianov, Organosilicon Compounds [In Russian] (Moscow, 1955).

[3] G. Aston and R. M. Kennedy, J. Am. Chem. Soc. 69, 2692 (1947).

[4] F. Whitmore, L. H. Sommer, et al., J. Am. Chem. Soc. 68, 475 (1946); L. J. Tyler, et al., J. Am. Chem. Soc. 70, 2876 (1948); 69, 981 (1947).

[5] L. G. Makarova and A. N. Nesmeyanov, Zhur. Obshchei Khim. 9, 171 (1939).

[6] R. Wintgen, Ber. 52, 724 (1919).

[7] R. O. Sauer, et al., J. Am. Chem. Soc. 68, 962 (1946).

[8] H. Emeleus and S. Robinson, J. Am. Chem. Soc. 69, 1952 (1947).

[9] Ch. E. Waring, Trans. Farad. Soc. 36, 1142 (1940).

[10] Ch. E. Waring, J. Am. Chem. Soc. 67, 540 (1945).

[11] D. F. Helm and E. Mach, J. Am. Chem. Soc. 59, 60 (1937).

DIPOLAR IONS FORMED BY PROTON DETACHMENT FROM THE NH GROUP

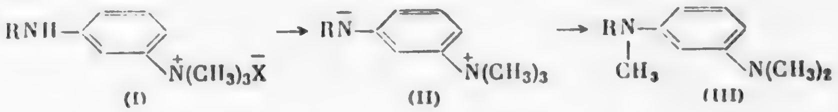
XIV. DERIVATIVES OF m-AMINODIMETHYLANILINE

M. N. Okorokova and A. M. Simonov

All-Union Correspondence Institute of Textile and Light Industries
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 239-241, January, 1960
Original article submitted October 6, 1958

It was previously shown [1] that under the action of alkalies, quaternary ammonium salts of the benzene series containing a p-nitrobenzoylamino- or a p-nitrobenzenesulfamino group in the para-position to the onium N atom are converted into dipolar ions which rearrange to N-alkylanilides on fusion. In continuation of this work we attempted to synthesize dipolar ions of analogous structure in which the onium N atom is in the meta-position to the NH group and to investigate the possibility of their isomerization. It seemed possible that the formation of dipolar ions of this type would proceed with greater facility than that of their para-isomers because the inductive effect of the onium atom on the NH group in the meta-position to it would be stronger [2].

Experiment shows that in aqueous solution, under the action of ammonia, a quaternary salt of the structure indicated resembles the para-isomer in being easily converted into a dipolar ion (II). Contrary to our hypothesis, however, it was not possible to convert a quaternary salt containing the p-nitrobenzoylamino group in the meta-position to the onium N- atom (I, R = p-$NO_2C_6H_4CO$) into a dipolar ion in an aqueous medium. Nor under these conditions is a betaine formed from a quaternary salt containing a benzoylamino group in the para-position to the trimethylammonium group.



Dipolar ion (II) resembles dipolar ions of analogous structure containing an onium group in the para-position to the azeniate N atom [1, 3] in being converted by fusion into the N-methylanilide (III); the structure of the latter was verified by reverse synthesis.

EXPERIMENTAL

3-(p-Nitrobenzenesulfamino)-N,N-dimethylaniline. Orange crystals (from alcohol) with m. p. 138-139°, soluble in benzene.

Found %: S 9.95. $C_{14}H_{15}O_4N_3S$. Calculated %: S 9.98.

Methyl-p-toluenesulfonate of 3-(p-nitrobenzenesulfamino)-N,N-dimethylaniline. Colorless crystals (from dilute alcohol) with m. p. 216-218°.

Found %: S 12.53, 12.55. $C_{22}H_{25}O_7N_3S_2$. Calculated %: S 12.63.

Methylbetaine of 3-(p-nitrobenzenesulfamino)-N,N-dimethylaniline. A 25% ammonia solution was added dropwise to a warm solution of 0.51 g of quaternary salt in 4 ml of water until a faint odor had developed. The precipitate was washed with water and dried in a desiccator over phosphorus pentoxide. Yield 0.27 g. Yellow plates melting at about 140°, soluble in alcohol, acetone and pyridine, insoluble in benzene. On standing in water vapor the betaine adds on two molecules of water.

Found %: S 9.39. $C_{15}H_{17}O_4N_3S$. Calculated %: S 9.56.

Isomerization of the betaine. The betaine (0.6 g) was placed in a test tube which was closed with a calcium chloride tube and inserted in an oil bath heated to 180°. In the course of 10 minutes, the temperature was raised to 200° and held there for 5 minutes. After the melt had cooled, it was repeatedly extracted with ether; the extract was washed with alkali and dried with potassium carbonate. After the ether had been driven off, the residue was crystallized from alcohol. Yield 0.23 g. Yellow-orange crystals with m. p. 131-132°. The compound was identical with the 3-dimethylamino-N-methylanilide of p-nitrobenzenesulfonic acid prepared from trimethyl-m-phenylenediamine as described below.

3-Dimethylamino-N-methylanilide of p-nitrobenzenesulfonic acid. N,N,N'-Trimethyl-m-phenylenediamine (1 g), prepared from m-aminodimethylaniline [4], was dissolved in dry pyridine and added to a solution of 1.4 g of p-nitrobenzenesulfochloride. The next day the solution was diluted with water, and the precipitate was filtered and recrystallized from alcohol. M. p. 131.5-132°.

Found %: N 12.54, 12.54. $C_{15}H_{17}O_4N_3S$. Calculated %: N 12.53.

Methyl-p-toluenesulfonate of 3-(p-nitrobenzoylamino)-N,N-dimethylaniline. Colorless crystals (from aqueous methanol) with m. p. 226-228°. A yellow color appeared when dilute alkali was added to the aqueous solution of the salt, but a dipolar salt (or its hydrate) was not formed. Addition of concentrated alkali to the solution only leads to formation of an emulsion.

Found %: S 6.76. $C_{23}H_{25}O_6N_3S$. Calculated %: S 6.80.

Methyl-p-toluenesulfonate of 4-benzoylamino-N,N-dimethylaniline. Snow-white crystals (from alcohol) with m. p. 275-277°. Addition of alkali to the aqueous or aqueous alcoholic solution of the salt did not lead to formation of a precipitate of the base or betaine.

Found %: S 7.51. $C_{23}H_{26}O_4N_2S$. Calculated %: S 7.51.

SUMMARY

New data are presented for the synthesis of dipolar ions from onium salts containing an acylamino group, and for their isomerization.

LITERATURE CITED

[1] A. M. Simonov and M. N. Okorokova, Zhur. Obshchei Khim. 27, 1941 (1957).*

[2] J. Roberts, R. Clement, and J. Drysdale, J. Am. Chem. Soc. 73, 2181 (1951).

[3] A. M. Simonov, Zhur. Obshchei Khim. 25, 2278 (1955).*

[4] F. King, K. Acheson, and A. Yorke, J. Chem. Soc. 1948, 1926.

* Original Russian pagination. See C. B. translation.

β-CHLOROVINYL KETONES OF THE HETEROCYCLIC SERIES

N. K. Kochetkov, É. E. Nifant'eva, and L. V. Nifant'eva

Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 241-245, January, 1960

Original article submitted September 30, 1958

The great versatility of β-chlorovinyl ketones in chemical syntheses [1] is an inducement to attempts at synthesis of fresh representatives of this class of compounds. Up to the present time methods have been developed for synthesis of alkyl-β-chlorovinyl ketones [2, 3], aryl-β-chlorovinyl ketones [3, 4], alkenyl-β-chlorovinyl ketones [5], some haloalkyl-β-chlorovinyl ketones [6, 7], and 2-chloro-1-acylcyclopentenes-1 [8]. Representatives of this series containing heterocyclic radicals have not hitherto been known; in view, however, of the great reactivity of β-chlorovinyl ketones, the preparation of heterocyclic representatives is of interest in connection with their further utilization for synthesis of difficultly accessible heterocyclic compounds.

In this paper we describe the synthesis of some β-chlorovinyl ketones containing five-membered heterocyclic radicals. It was found that aromatic five-membered heterocyclic acid chlorides (from 2-furoic, thiophene-2-carboxylic, and selenophene-2-carboxylic acids) enter with facility into condensation with acetylene in similar fashion to their aliphatic and aromatic analogs and give the corresponding β-chlorovinyl ketones.

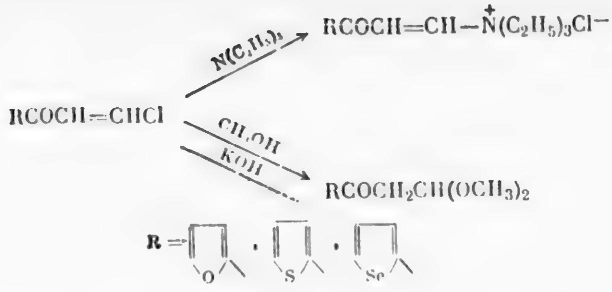
$$RCOCl + CH{\equiv}CH \xrightarrow{AlCl_3} RCOCH{=}CHCl$$

R = 

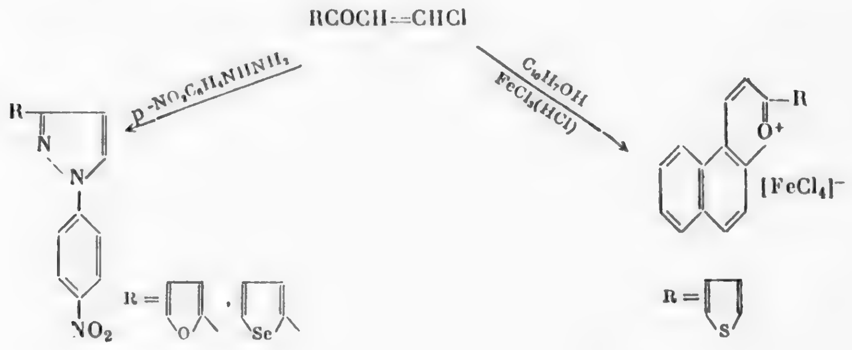
The reaction was performed under the conditions previously developed for condensation of aromatic acid chlorides [4], i.e., at raised temperature (30-40°) and with use of a previously prepared complex of the acid chloride and aluminum chloride. At lower temperatures (used in the synthesis of aliphatic β-chlorovinyl ketones [2]) the reaction scarcely takes place. This is an illustration of the well-known analogy between five-membered heterocycles containing one heteroatom and aromatic compounds.

Yields of thienyl(2)- and selenyl(2)-β-chlorovinyl ketones were fairly high, whereas the synthesis of the corresponding furan compounds was accompanied by very considerable resinification associated with the instability of the furan nucleus. It was found most desirable not to carry the condensation of 2-furoyl chloride with acetylene to completion; resinification was thereby markedly reduced and a considerable quantity of acid chloride was recovered; a yield of about 40% of furyl(2)-β-chlorovinyl ketone (calculated on the reacted acid chloride) could then be attained.

The prepared heterocyclic β-chlorovinyl ketones are readily fusible solids or liquids. They have a pungent odor and are rather unstable in storage, in these respects resembling other representatives of this series. Their chemical behavior is also entirely analogous to that of other β-chlorovinyl ketones. They react smoothly with tertiary amines [9] with quantitative conversion into the corresponding quaternary ammonium salts which are crystalline solids and can serve for characterization of the β-chlorovinyl ketones. This reaction demonstrates the great lability of their halogen atom. They react smoothly with alcohol in presence of alkali [10] to form β-ketoacetals. The latter have recently attracted much attention.



The β-chlorovinyl ketones can also be successfully employed for heterocyclic syntheses to give compounds containing various heterocyclic nuclei. They condense smoothly, for example, with p-nitrophenylhydrazine to give pyrazole derivatives containing furanic or selenophenic substituents. Condensation of thienyl-(2)-β-chlorovinyl ketone with β-naphthol in presence of ferric chloride in hydrochloric acid [11] gave 2-thienyl-(2')-naphtho-(1,2:5,6)-pyrylium ferrichloride.



The data presented in this paper show that the general method of synthesis of β-chlorovinyl ketones by condensation of acid chlorides with acetylene is also applicable to the heterocyclic series. Some of the transformations of the heterocyclic β-chlorovinyl ketones which have been studied are indicative of the general value of these compounds in syntheses of the most diverse compounds.

EXPERIMENTAL

Furyl-(2)-β-chlorovinyl ketone. To a solution of 40 g of 2-furoyl chloride in 150 ml of dry dichloroethane at 0-5° was gradually added 45 g of aluminum chloride; acetylene was passed into the resulting complex for 7 hours at 33-35°, after which the mixture was decomposed with ice. The lower layer was separated, the aqueous layer was twice extracted with dichloroethane and the dichloroethane extracts were added to the main portion of product, which was then dried over calcium chloride. Distillation gave 24 g of the original acid chloride and 8 g (41% calculated on the reacted acid chloride) of furyl-(2)-β-chlorovinyl ketone with b. p. 102-105° (10 mm); after redistillation the substance had the following constants:

B. p. 103-105° (10 mm), m. p. 46-48°.

Found %: C 53.38, 53.25; H 3.73, 3.63. $C_7H_5O_2Cl$. Calculated %: C 53.50; H 3.43.

Yellowish crystals with a pungent odor, soluble in common organic solvents; darken fairly quickly on keeping.

Mixing of equimolar quantities of furyl-(2)-β-chlorovinyl ketone and triethylamine in ethereal solution leads to a nearly quantitative yield of triethyl-(β-furylvinyl)-ammonium chloride; light-yellow, very hygroscopic crystals with m. p. 125-126°, insoluble in benzene, chloroform and ether.

Found %: N 5.68, 5.80. $C_{13}H_{20}O_2NCl$. Calculated %: N 5.43.

Thienyl-(2)-β-chlorovinyl ketone. The above procedure was followed. Starting components were 25.5 g of thiophene-2-carboxylic acid chloride and 25.5 g of aluminum chloride in 90 ml of dichloroethane; passage of acetylene for 8 hours at 35-38° gave 19.7 g (65%) of thienyl-(2)-β-chlorovinyl ketone with b. p. 154-156.5° (23 mm). The product set to a crystalline mass on keeping. After recrystallization from benzene the pure substance had m. p. 25.5-27°.

Found %: C 48.94, 48.98; H 2.81, 2.89. C_7H_5OSCl. Calculated %: C 48.75; H 2.97.

Yellow crystals with a pungent odor, easily soluble in ether, chloroform and acetone, less soluble in ligroine and benzene. Unstable in storage.

Reaction of thienyl-(2)-β-chlorovinyl ketone with triethylamine led to nearly quantitative yield of triethyl-(β-thienylvinyl)-ammonium chloride; crystals with m. p. 113-115°.

Found %: C 56.36, 56.42; H 7.77, 7.55. $C_{13}H_{20}ONSCl$. Calculated %: C 56.80; H 7.37.

Selenyl-(2)-β-chlorovinyl ketone. The complex from 24.7 g of selenophene-2-carboxylic acid chloride and 18.4 g of aluminum chloride in 70 ml of dichloroethane was treated for 10 hours with a stream of acetylene at 48-51°. There was obtained 12.3 g (45%) of selenyl-(2)-β-chlorovinyl ketone with b. p. 132-135° (7 mm). After redistillation the product had b. p. 133-134° (7 mm), $n^{20}D$ 1.6540, d^{20}_4 1.6621.

Found %: C 38.19, 38.21; H 2.65, 2.69. C_7H_5OSeCl. Calculated %: C 38.47; H 2.29.

A viscous liquid with a pungent odor, darkening on keeping.

Dimethylacetal of furoyl-(2)-acetaldehyde. To a solution of 1 g of potassium hydroxide in 10 ml of methanol was added (with stirring and cooling to −10°) 2.5 g of furyl-(2)-β-chlorovinyl ketone. After stirring for 1 hour, the mixture was stood overnight and then poured into water and extracted with ether. The ethereal extracts were dried over magnesium sulfate. Distillation gave 1.9 g (64%) of the dimethylacetal of furoyl-(2)-acetaldehyde with b. p. 120-122° (9 mm). After redistillation the product had b. p. 122-123° (10 mm), $n^{20}D$ 1.4988, d^{20}_4 1.1800.

Found %: C 58.80, 59.01; H 6.49, 6.65. $C_9H_{12}O_4$. Calculated %: C 58.87; H 6.50.

A yellowish liquid giving a coloration with ferric chloride, miscible with organic solvents, insoluble in water.

Dimethylacetal of thenoyl-(2)-acetaldehyde. Prepared on similar lines to the preceding product from 4 g of thienyl-(2)-β-chlorovinyl ketone and 1.3 g of potassium hydroxide in 13 ml of methanol. Distillation gave 2.5 g (53%) of the dimethylacetal of thenoyl-(2)-acetaldehyde; b. p. 147-148° (8 mm), $n^{20}D$ 1.5146, d^{20}_4 1.1910.

Found %: C 54.41, 54.39; H 6.21, 6.12. $C_9H_{12}O_3S$. Calculated %: C 54.23; H 6.00.

A yellowish liquid giving a coloration with ferric chloride, miscible with organic solvents, insoluble in water.

Dimethylacetal of selenoyl-(2)-acetaldehyde. Prepared as above from 3.6 g of selenyl-(2)-β-chlorovinyl ketone, 1 g of potassium hydroxide and 10 ml of methanol. Distillation gave 2.3 g (57%) of the dimethylacetal with b. p. 151-152° (6 mm), $n^{20}D$ 1.5626, d^{20}_4 1.4910.

Found %: C 43.28, 43.36; H 5.05, 4.93. $C_9H_{12}O_3Se$. Calculated %: C 43.72; H 5.85.

A yellowish liquid giving a coloration with ferric chloride, miscible with organic solvents, insoluble in water.

3-Furyl-(2')-1-(p-nitrophenyl)-pyrazole. Furyl-(2)-β-chlorovinyl ketone (0.2 g) and p-nitrophenylhydrazine (0.2 g) in 20 ml of anhydrous alcohol were heated for 8 hours on a water bath, and the mass was left standing for several days. The greater part of the solvent was distilled off, and the crystals were filtered and recrystallized from alcohol to give 0.2 g (62%) of 3-furyl-(2')-1-(p-nitrophenyl)-pyrazole with m. p. 70.5-72°.

Found %: N 16.23, 16.22. $C_{13}H_9O_3N_3$. Calculated %: N 16.51.

Orange prisms, readily soluble in acetone, moderately in alcohol, poorly in benzene and ligroine.

3-Selenyl-(2')-1-(p-nitrophenyl)-pyrazole. Prepared as above from 0.96 g of selenyl-(2)- β-chlorovinyl ketone and 0.75 g of p-nitrophenylhydrazine in 60 ml of anhydrous alcohol. Yield 0.9 g (63%) of 3-selenyl-(2')-1-(p-nitrophenyl)-pyrazole with m. p. 100-101°.

Found %: N 13.18, 13.05. $C_{13}H_9O_2N_3Se$. Calculated %: N 13.29.

Orange prisms, moderately soluble in alcohol, less soluble in benzene, poorly soluble in ligroine.

2-Thienyl-(2')-naphtho-(1,2:5,6)pyridinium ferrichloride. A solution of 0.85 g of ferric chloride in 1.5 ml of concentrated hydrochloric acid was run into a solution of 0.2 g of thienyl-(2)- β-chlorovinyl ketone and 0.17 g of β-naphthol in 4.2 ml of glacial acetic acid. The reaction mass stood for 24 hours. The precipitate was filtered and crystallized from glacial acetic acid to give 0.35 g (66%) of product with m. p. 176-177°.

Found %: C 44.55, 44.36; H 2.49, 2.70. $C_{17}H_{11}OSFeCl_4$. Calculated %: C 44.45; H 2.39.

Bright-red crystals, moderately soluble in hot acetic acid, insoluble in benzene and chloroform, decomposed by water.

SUMMARY

1. The general method of synthesis of β-chlorovinyl ketones by condensation of acid chlorides with acetylene is extended to β-chlorovinyl ketones containing five-membered heterocyclic radicals.

2. It is shown that the chemical transformations of heterocyclic β-chlorovinyl ketones are entirely similar to those of other representatives of this series.

LITERATURE CITED

[1] N. K. Kochetkov, Uspekhi Khimii, 32, 24 (1955).

[2] A. N. Nesmeyanov, N. K. Kochetkov, and M. I. Rybinskaya, Izvest. Akad. Nauk SSSR, Otdel, Khim. Nauk 1950, 350.

[3] V. T. Klimko, V. A. Mikhalev, and A. P. Skoldinov, Zhur. Obshchei Khim. 27, 370 (1957).*

[4] N. K. Kochetkov, A. Ya. Khorlin, and M. Ya. Karpeiskii, Zhur. Obshchei Khim. 26, 595 (1956).*

[5] N. K. Kochetkov, A. Ya. Khorlin, B. P. Gottikh, and A. N. Nesmeyanov, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk. 1956, 1056.*

[6] N. K. Kochetkov, A. N. Nesmeyanov, and N. A. Semenov, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk, 1952, 87.*

[7] N. K. Kochetkov and A. Ya. Khorlin, Zhur. Obshchei Khim. 28, 1937 (1958).*

[8] N. K. Kochetkov, É. E. Nifant'ev, and V. N. Shibaev, Zhur. Obshchei Khim. 29, 2324 (1959).*

[9] V. T. Klimko, A. Ya. Khorlin et al., Zhur. Obshchei Khim. 27, 62 (1957).*

[10] A. N. Nesmeyanov, N. K. Kochetkov, and M. I. Rybinskaya, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk. 1951, 395.

[11] A. N. Nesmeyanov, N. K. Kochetkov, and M. I. Rybinskaya, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk 1953, 479.*

* Original Russian pagination. See C. B. translation.

REACTION OF THIOCYANIC ESTERS WITH AMINES

L. L. Konovalova and V. F. Ust'-Kachkintsev

Perm State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 246-250, January, 1960

Original article submitted August 23, 1958

Mustard oils, as is known, react vigorously with primary and secondary amines to form stable thiourea derivatives that are not dissociated by heat. On the property diagrams of such systems clearly defined singular points always correspond to a rational 1 : 1 ratio of the components. As a rule, homogeneous solutions of mustard oils with amines have a high electroconductivity, in which connection the conductivity shows constant increase for a long time when such mixtures are stored. This is also true of systems formed from mustard oils and tertiary amines, which also possess a substantial electroconductivity, whereas measurement of other properties of these systems indicates that noticeable chemical reaction between the components is absent [1-3].

The reasons for mixtures of mustard oils and amines showing a high electroconductivity have remained obscure, and authors were usually forced to limit themselves to general statements of peculiar, current-conducting complexes arising in the solutions. Recently, S. P. Miskidzh'yan [4] in a series of papers offers convincing evidence that the high conductivity of the indicated solutions is due to the presence of thiocyanic salts. According to this author, the thiocyanates are formed as the result of the mustard oil isomerizing to the thiocyanic ester, which, similar to the alkyl halides, reacts with amines according to the acid-base type of reaction with the formation of substituted ammonium salts.

A comparison of the behavior of the systems formed by amines with thiocyanic and isothiocyanic esters is of undoubted interest. With this in mind, we undertook a study of the reaction of ethyl thiocyanate with differently substituted aromatic amines. The results of measuring the density, viscosity and electroconductivity of mixtures of ethyl thiocyanate with aniline, piperidine, pyridine and dimethylaniline are given below.

EXPERIMENTAL

The amines after drying over KOH were distilled. The following fractions were collected: aniline 181.3 to 181.5° (769 mm), d^{25}_4 1.0181; pyridine 114-114.5° (746 mm), d^{25}_4 0.9761; piperidine 106-107° (770 mm), d^{25}_4 0.8560; dimethylaniline 191-192° (778 mm), d^{25}_4 0.9513.

Ethyl thiocyanate was synthesized from potassium thiocyanate and ethyl iodide [5]. After drying over anhydrous sodium sulfate the product was distilled twice. B. p. 144-146° (758 mm), d^{25}_4 1.0058.

It proved that in all cases the components mixed with very little heat evolution. The solutions were prepared on a weight basis and were kept in the dark in sealed ampules or in special test tubes with well-fitting ground-glass stoppers. The solutions gradually darken on standing; this is especially true of the aniline and piperidine solutions. Even within several days after preparation, mixtures of ethyl thiocyanate with these amines turn dark-brown and become quite opaque.

A pycnometer was used to determine the density, while an Ostwald viscosimeter was used to measure the viscosity. A vessel fitted with smooth platinum electrodes was used to measure the electroconductivity. The temperature in all of the measurements was maintained exact to ± 0.05°. The composition of the solutions was expressed in mole percent.

Ethyl thiocyanate – piperidine. The reaction of ethyl thiocyanate with piperidine is quite rapid. This may be judged by the change in the viscosity of the solutions with time. On the day of preparation, the viscosity of the mixtures changes so rapidly that the measurements cannot be made with satisfactory accuracy. The reaction rate diminishes with time, but even after two months of standing the viscosity of the solutions continues to increase. In Fig. 1, we have shown the change in the viscosity and the electroconductivity of one of the solutions. The solutions containing 50-60% of amine show the greatest changes. In this concentration range the viscosity isotherms of the system show a maximum, which becomes more clearly expressed the longer the standing. The greatest deviation from additivity in the density of the solutions also occurs in approximately the same concentration range (Fig. 2).

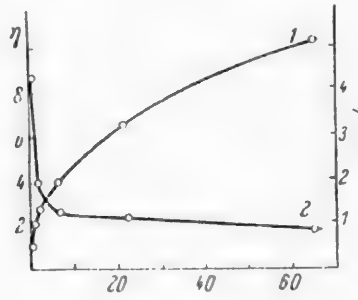


Fig. 1. Change in viscosity (1) and electroconductivity (2) of 50% mixture of ethyl thiocyanate and piperidine with time at 25°.

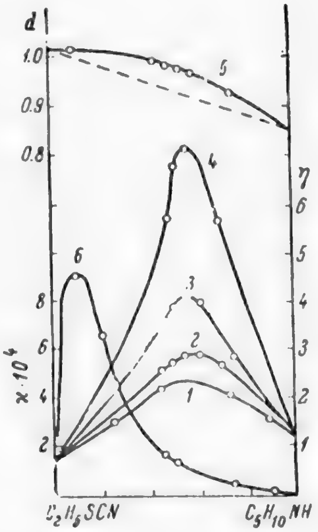


Fig. 2. System ethyl thiocyanate–piperidine at 25°. 1-4) Viscosity after 1, 2, 7, and 20 days; 5) density after 1 day; 6) electroconductivity after 1 day.

The electroconductivity of the mixtures exhibits more complex changes with time. At the start it rises very rapidly, and then it drops just as rapidly for a day. After this the electroconductivity continues to decrease at a gradual rate (Fig. 1). Considering the change in viscosity with time, it may be assumed that the concentration of the ions in the solutions and the viscosity increase continuously, in which connection these changes compensate each other to some degree; in the final analysis, the electroconductivity changes very little with "increase." The electroconductivity isotherm is expressed by a smooth curve with a maximum shifted toward the ethyl thiocyanate ordinate (Fig. 2).

Ethyl thiocyanate – aniline. The internal friction isotherm of the system does not give any indications of reaction between the components. The viscosity of the mixtures increases constantly with increase in the aniline content, forming a curve convex to the composition axis. In contrast, the density isotherm unequivocally indicates that chemical reaction exists in the system.

Only the electroconductivity of the solutions shows substantial change during storage. The shape of the curve fails to show any peculiar changes, but the value of the electroconductivity increases sharply. In 4.5 months the conductance of the mixtures increases by 15 to 20 times (Fig. 3).

On long storage (up to 1.5 years) of the mixtures in sealed ampules, the solutions belonging to the middle portion of the diagram, show underneath the layer of mobile dark-brown liquid a small amount of transparent, slightly colored crystals with a melting point of about 200°.

Ethyl thiocyanate – dimethylaniline. The viscosity and density curves of the system, taken several days after preparation of the solutions, show a slight negative deviation from additivity. The specific electroconductivity of the mixtures is very small and does not lie outside the limits of the values obtained for the pure components. The results of the measurements are plotted in Fig. 4.

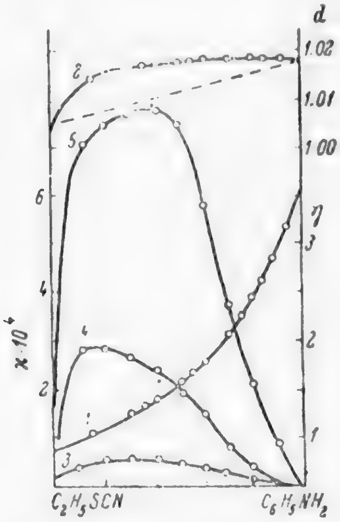


Fig. 3. System ethyl thiocyanate–aniline at 25°. 1) Viscosity after 1 day; 2) density after 1 day; 3-5) electroconductivity after 1, 15, and 140 days.

Ethyl thiocyanate – pyridine. Pyridine and ethyl thiocyanate react very slowly at room temperature, for which reason the diagram of the properties of the system changes substantially during storage. The density values of the solutions, measured within a day after preparing

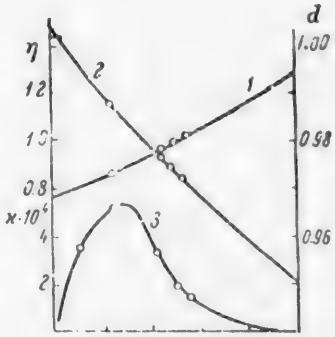


Fig. 4. System ethyl thiocyanate–dimethylaniline at 25°. 1) Viscosity; 2) density; 3) electroconductivity after 8 months.

the mixtures, fall well on the additivity straight line. The viscosity isotherm taken in the initial period of storage is characterized by a curve with a distinct minimum in the region close to the equimolar ratio of the components. The conductance of the solutions is small, and the electroconductivity isotherm is expressed by a curve with a very diffuse maximum.

The measurements made after two months give results that are quite different from those initially obtained. The density of the mixtures increases. The viscosity of the solutions also increases, especially at high pyridine concentrations, which results in a change in the shape of the viscosity curve itself. The minimum is retained, but it is shifted strongly toward the ethyl thiocyanate side; the portion of the curve going from the pyridine ordinate assumes an S-like shape (Fig. 5). The changes in the properties with time continue to increase, which leads to a further transformation of the diagram. The viscosity and density isotherms taken 1.5 years after preparation of the mixtures are shown in Fig. 5. As can be seen, the deviation of the density of the solutions from additivity becomes very large; the viscosity isotherm is expressed by a curve with a maximum, corresponding to 70% pyridine. The electroconductivity of the solutions increases substantially and reaches very high values (Fig. 6). A second characteristic of the electroconductivity of the system is the symmetrical shape of the conductance curve. It should be mentioned that mixtures of pyridine with mustard oils also have a high electroconductivity and a relatively symmetrical position of the maximum [2].

The obtained results clearly show that the systems formed by amines with thiocyanic and isothiocyanic esters behave quite differently. The properties of the systems containing isothiocyanic esters are determined by the degree of substitution of the amine; in systems containing primary and secondary amines the vigorous reaction of forming thioureas leads to diagrams of the singular type, while in the case of tertiary amines the systems that are formed differ but slightly from the normal. Thiocyanic esters react with amines in a common manner, independent of the degree of substitution of the amine. It may be assumed that in such systems the formation of substituted ammonium salts will go practically to completion; in the final analysis this should lead to the creation of diagrams of the rational type.

The reaction rate, depending on the individual properties of the amine, is not the same for different systems, but, as follows from the obtained data, in all cases it is very small at room temperature. The components react very slowly, and reaction extends over a long time. In connection with this the isotherms – isochrones of the properties characterize only some intermediate state of the systems in the process of reaching equilibrium.

The investigated systems are analogous to the systems formed by pyridine with butyl iodide and butyl bromide [6]. Alkyl iodides and bromides are more reactive than the chlorides, and much more reactive than the thiocyanates. In addition, the indicated work was done at elevated temperature, for which reason it proved possible to obtain a continuous series of property isotherms in a comparatively short period of time, changing from the initial isotherms, close to ideal, to isotherms that approached the singular type in their shape.

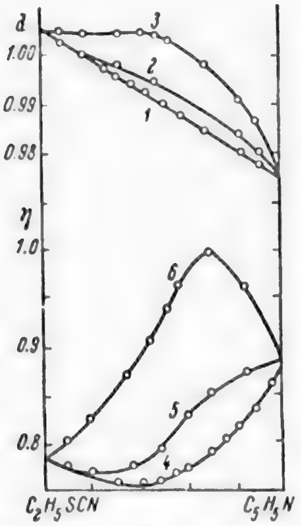


Fig. 5. System ethyl thiocyanate–pyridine at 25°. 1-3) Density after 1 day, 2 months, and 1.5 years; 4-6) viscosity after 1 day, 2 months, and 1.5 years.

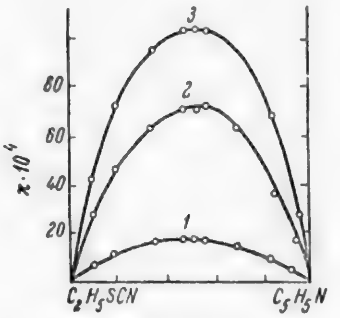


Fig. 6. Electroconductivity of mixtures of system ethyl thiocyanate – pyridine. 1 and 2) After 2 months and 1.5 years at 25°; 3) after 1.5 years at 50°.

The property isotherms for systems containing thiocyanic esters, observed even after long storage, must be regarded as having been obtained under conditions quite distant from the final equilibrium state. This undoubtedly is the reason for the fact that the position of the extreme points on the property isotherms does not correspond to the rational ratio of the components.

SUMMARY

1. The electroconductivity, density, and viscosity of the systems ethyl thiocyanate – piperidine, ethyl thiocyanate – aniline, ethyl thiocyanate – dimethylaniline, and ethyl thiocyanate – pyridine, were measured at the end of different periods of time after preparation of the solutions.

2. On long storage the properties of the mixtures change toward a constantly greater deviation from additivity. The solutions exhibit substantial electroconductivity, and an especially high conductivity is observed for mixtures composed of ethyl thiocyanate and pyridine.

3. The fact that the properties of the solutions change with time is due to the slow reaction rate.

LITERATURE CITED

[1] N. A. Trifonov and S. I. Cherbov, Izvest. Perm. Biol. Nauck.-Issledovatel. Inst. 6, 247 (1928).

[2] N. K. Voskresenskaya, Uchenye Zapiski, Saratov. Gosudarst. Univ. 6, 227 (1927).

[3] N. A. Trifonov, Izvest. Perm. Biol. Nauch.-Issledovatel. Inst. 7, 343 (1931); N. A. Trifonov, K. I. Samarina, and V. F. Ust'-Kachkintsev, Zhur. Fiz. Khim. 29, 513 (1955).

[4] S. P. Miskidzh'yan and F. N. Kozlenko, Soobshcheniya Vsesoyuz. Khim. Obshchestva im. D. I. Mendeleeva 1, 27 (1953); S. P. Miskidzh'yan, Zhur. Obshchei Khim. 26, 1046 (1956);* 27, 1755 (1957);* 28, 276 (1958);* S. S. Kirilyuk and S. P. Miskidzh'yan, Zhur. Fiz. Khim. 31, 1614 (1957).

[5] M. Schlagdenhauffen, Ann. Chim. et Phys. [3] 56, 297 (1859).

[6] E. A. Bekturov, Vestnik Akad. Nauk Kazakh. SSR 8, 83 (1957); cited from author's abstract of dissertation "Time Factor in Physicochemical Analysis of Liquid Systems," (Alma-Ata, 1958).

* Original Russian pagination. See C. B. translation.

COPOLYMERIZATION OF UNSATURATED POLYESTERS WITH VINYL MONOMERS

III. PECULIARITIES OF THE COPOLYMERIZATION OF UNSATURATED POLYESTERS WITH VINYL MONOMERS*

S. S. Spasskii, A. V. Tokarev, M. A. Mikhailova, T. V. Molchanova, and M. E. Mat'kova

Institute of Chemistry, Ural Branch, Academy of Sciences, USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 250-257, January, 1960

Original article submitted July 29, 1958

The reaction of unsaturated polyesters with vinyl monomers yields crosslinked copolymers, which have found wide use in the production of reinforced plastics. For a proper solution of the problems associated with the technology of manufacturing reinforced plastics from these resins, it is necessary to establish the interrelationships existing between the ratio of the starting components and the composition of the copolymers.

The copolymerization reaction, as is known, is characterized by constants that are determined by the relative activity of the monomers participating in the reaction. The copolymerization constants for the initial stages of the copolymerization of an unsaturated polyester [poly (ethylene glycol fumarate)] with a vinyl monomer (methyl methacrylate) were determined by Gordon, Grieveson, and McMillan, who used the differential equation of the composition of the copolymers for this purpose [1]. Hayes and Hunter [2], and also Wycherly [3], attempted to use the copolymerization constants, characterizing the behavior of low-molecular mono- and diesters of maleic and fumaric acids, for calculating the composition of the copolymers of an unsaturated polyester with styrene. However, as is correctly indicated by Wycherly, such an assumption is valid only for the very early stages of the reaction. Mention is also made by Robertson and Shepherd [4] that the method used by Wycherly to calculate the composition is greatly simplified and is not always applicable.

Actually, the reaction for the copolymerization of unsaturated polyesters with vinyl monomers can be arbitrarily divided into two stages, proceeding before and after gel formation. At the start of reaction the linear polyester and the vinyl monomer are found in the system. For practical purposes the fumaric linkages of the linear polyester may all be considered to be equal in activity. After formation of the crosslinked molecules the reaction conditions change. The crosslinked molecules will have as a "suspension" a series of consecutively linked polyester units, containing unreacted double bonds. The double bonds of the tridimensional "suspensions" will not be equivalent in activity. Those double bonds that are located nearer the place where the tridimensional network forms could be blocked due to steric hindrance.

In studying the copolymerization of poly (1,3-butylene glycol fumarate) with styrene it was established that only about 50% of the double bonds of the polyester react [5].

* Communications I and II see: Zhur. Fiz. Khim. 33, 249, 554 (1959).

In investigating the copolymers of poly(propylene glycol fumarate) with styrene by the methods of spectroscopy and analysis of the hydrolysis products, it was also shown by Hayes, Read and Vaughan [6] that not all of the bonds of the polyester react during copolymerization.

In the copolymerization of unsaturated polyesters with vinyl monomers, the first stage of the reaction, where the linking of the linear molecules of the polyester occurs, is not determining for the final composition of the copolymers, since their formation goes mainly with involvement of the crosslinked molecules, in which a portion of the double bonds is already blocked. Therefore, in order to characterize later stages of the reaction using copolymerization constants it is necessary to introduce a correction in the composition of the reaction mixture for the blocked double bonds of the polyester. A description of the initial stage of the process is altered somewhat by such a correction, but it is possible to assume that the error will not exceed the limits of accuracy of determining the copolymerization constants.

It was shown [5] that the complete equation of Mayo and Lewis can be used to calculate the constants for the copolymerization of unsaturated polyesters with vinyl monomers, provided a correction is made in the composition of the reaction mixture for the unreacted double bonds of the polyester, passing without change into the copolymer. The values of the constants calculated in this manner for different degrees of conversion were close. For the constants to show a constancy for different degrees of conversion is evidently due to the fact that in the given case the reaction goes under more monotypic conditions than prevail in the copolymerization of monomers, one of which contains two double bonds.

In the copolymerization of monomers with two double bonds, the formation of the copolymers goes through the stages of forming linear, branched, and tridimensional molecules, and reaction of the tridimensional molecules with the intermediate and monomeric compounds. Here, the copolymerization constants show considerable change during the course of reaction in some cases. Thus, for the system styrene – ethylene glycol dichloroacrylate [7] the determined copolymerization constants were $r_1 = 0.6$ and $r_2 = 0.1$ for the initial stage, and $r_1 = 0.04$ and $r_2 = 0.2$, for the deep stage. The copolymerization constants for the system poly(1,3-butylene glycol fumarate) – styrene differ from the constants for the copolymerization of styrene with low-molecular esters of fumaric acid, which can be seen from the data in Table 1. Leavitt, Stannett, and Szwarc [8], having measured the "methyl affinity" of unsaturated polyesters and fumaric acid diesters, showed that the double bonds in these compounds have a close activity. Consequently, a change in the constants occurs because of the variable behavior of styrene in its copolymerization with polyesters and fumaric acid diesters, which can be explained in the following manner. The polyester "suspensions" of the tridimensional molecule screen its radical end. The admittance of monomers to the radical will be more difficult the greater the size of the substituent at the double bond of the monomer. Styrene, having the phenyl group as substituent, experiences great difficulty in reacting with a radical having a tridimensional network.

It seemed of interest to determine how monomers with a different structure than styrene would behave in copolymerization with polyesters. In connection with this, we studied in the present paper the copolymerization of poly(1,3-butylene glycol fumarate) with vinylcarbazole, acrylonitrile, vinyl acetate and methyl methacrylate, and of poly(ethylene glycol fumarate) with vinyl acetate. It was established that vinylcarbazole does not copolymerize with the polyester. This fact supports the theory expressed regarding the influence of steric factors on the activity of vinyl monomers in copolymerization with polyesters. If styrene, having a phenyl ring at the double bond, shows a lower activity in its copolymerization with polyesters than when copolymerized with low-molecular esters of fumaric acid, then vinylcarbazole, having three connected rings as substituent at the double bond, will be completely unreactive in copolymerization with polyesters, since it obviously is unable to overcome the steric hindrance created by the presence of an extremely bulky substituent. The constants for the copolymerization of diesters and polyesters with different monomers are compared in Table 1. The method described in a previous communication [5] was used to compute the constants for the systems investigated in the present paper. From the data in Table 1, it can be seen that acrylonitrile, the same as styrene, shows a sharper lower activity when copolymerized with polyesters than when copolymerized with diesters. A slight decrease in activity can also be detected in the case of methyl methacrylate. The value of the constants for the copolymerization of polyesters with vinyl acetate is approximately of the same order as for fumaric acid diesters.

TABLE 1

Copolymerization Constants of Fumaric Acid Derivatives

System	r_1	r_2	Temperature
Diethyl fumarate – styrene [16]	0.07 ± 0.007	0.30 ± 0.02	60°
Poly (1,3-butylene glycol fumarate) – styrene [5]	3.00 ± 0.40	0.03 ± 0.03	60°
Diethyl fumarate – acrylonitrile [16]	0.00	8.00	60°
Poly (1,3-butylene glycol fumarate) – acrylonitrile	1.12 ± 0.40	1.03 ± 0.2	60°
Fumaronitrile – methyl methacrylate [1]	0.01	3.5 ± 0.5	60°
Poly (ethylene glycol fumarate) – methyl methacrylate [1]	0.35 ± 0.35	17.5 ± 7.5	60°
Poly (1,3-butylene glycol fumarate) – methyl methacrylate	0.5 ± 0.5	2.1 ± 0.30	60°
Diethyl fumarate – vinyl acetate [16]	0.444 ± 0.003	0.011 ± 0.001	60°
Poly (1,3-butylene glycol fumarate) – vinyl acetate	0.2 ± 0.2	0.15 ± 0.07	60°
Poly (ethylene glycol fumarate) – vinyl acetate	0.2 ± 0.1	0.020 ± 0.02	60°

The presented data indicate that monomers containing conjugated double bonds show a reduced activity when reacted with polyesters. This may be due to the appearance of additional steric hindrance in the copolymerization with polyesters. Molecules containing conjugated double bonds will be more rigid due to the limited internal rotation of the atomic groups attached to the single bond found between the two double bonds [9]. It is obvious that rigid molecules react more difficultly with the tridimensional radical than do flexible molecules. Vinyl acetate, not showing conjugation, does not change its activity when copolymerized with polyesters.

The difficulty of determining the constants for the copolymerization of unsaturated polyesters with vinyl monomers permits obtaining only approximate values. However, it is possible to calculate from these constants, with sufficient accuracy for practice, the conditions needed to obtain copolymers of uniform composition.

Using the equations of L. I. Gindin, A. D. Abkin, and S. S. Medvedev [10], and the method proposed by S. N. Ushakov, S. P. Mitsengendler and B. M. Polyatskina [11], we calculated the integral composition of the copolymers for the different systems of polyesters with methyl methacrylate and vinyl acetate. The composition diagrams are shown in Figs. 1 and 2.

The experimental and calculated data for the copolymers of poly (1,3-butylene glycol fumarate) and vinyl acetate are compared in Table 2. The calculated results show good agreement with the experimental. Analogous results were also obtained for the copolymers of the other systems.

The integral composition was calculated on the basis of the amount of reacted double bonds of the polyester contained in the copolymer. Based on the average amount of reacted double bonds, it is also possible to calculate the actual composition of the copolymer from the diagrams.

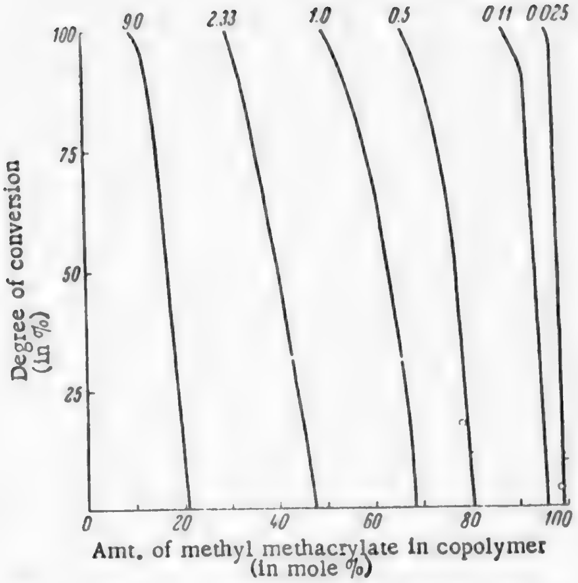


Fig. 1. Diagram of the integral composition for copolymers of the system poly(1,3-butylene glycol fumarate) – methyl methacrylate.

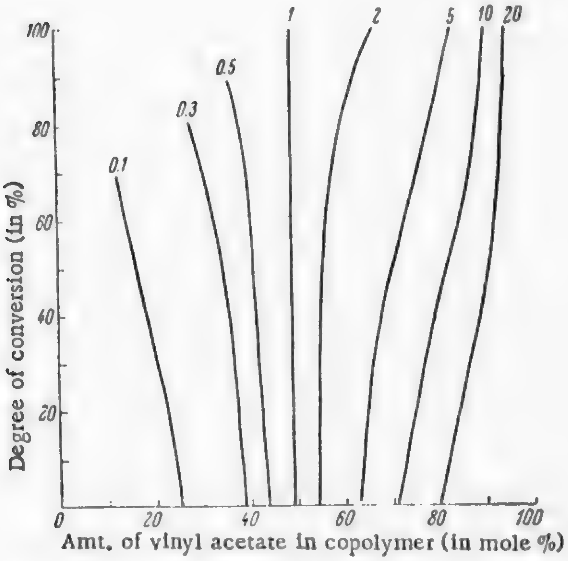


Fig. 2. Diagram of the integral composition for copolymers of the system poly(1,3-butylene glycol fumarate) – vinyl acetate.

TABLE 2

Composition of Poly(1,3-butylene glycol fumarate) – Vinyl Acetate Copolymers

Mole fraction of reacted polyester units in the copolymers	
calculated from the constants	determined experimentally
0.42	0.39
0.42	0.41
0.41	0.39
0.31	0.36
0.31	0.33
0.43	0.41

From the composition diagrams of the copolymers it can be seen that it is possible to obtain an azeotrope for the system poly(1,3-butylene glycol fumarate) – vinyl acetate if the starting components are taken in a 1 : 1 ratio. Methyl methacrylate does not give an azeotrope; however, the diagrams permit selecting such conditions that copolymers with the most uniform composition are obtained. Acrylonitrile, as can be seen from the copolymerization constants, gives an azeotrope at all ratios of the starting components.

EXPERIMENTAL

The polyesters poly(1,3-butylene glycol fumarate) and poly(ethylene glycol fumarate) were obtained by the polycondensation of maleic anhydride with the proper glycols. The condensation was run in a nitrogen atmosphere at 120° for 2 hours and at 190° to the desired acid number. As is known, under these conditions the maleic linkages are isomerized to the fumaric [12]. Maleic anhydride and the glycols were purified by vacuum distillation.

Poly(1,3-butylene glycol fumarate) had d^{20}_4 1.2279 and $n^{20}D$ 1.5102, acid number 46.2, and saponification number 630.40. Poly(ethylene glycol fumarate) had d^{20}_4 1.3623, acid number 53.6, and saponification number 721.6.

The vinylcarbazole, acrylonitrile, vinyl acetate and methyl methacrylate were purified by known procedures [13, 14]. Vinylcarbazole after purification had m. p. 65-66° and a nitrogen content of 7.21%. The constants of the purified acrylonitrile, methyl methacrylate and vinyl acetate are given in Table 3.

Copolymerization of the polyesters with acrylonitrile, vinyl acetate and methyl methacrylate was run in sealed glass ampules in a nitrogen atmosphere. The ampules were placed in a thermostat, where the temperature was maintained at 60 ± 0.1°. Benzoyl peroxide was used as reaction initiator. When the reaction had gone to the desired degree the ampules were removed from the thermostat and cooled in liquid nitrogen. To separate the tridimensional copolymer from the other reaction products, the contents of the ampules were treated with acetone containing traces of hydroquinone. The hydroquinone was added to prevent further polymerization of the unreacted starting products. After filtering the solution through a weighed glass filter the insoluble copolymer was washed well with acetone until the addition of water to the acetone wash failed to give a turbidity. This was usually achieved only after repeated treatment of the reaction products with acetone for several days. The copolymer after removal of the acetone-soluble products was dried in a vacuum oven at 80° to constant weight.

TABLE 3

Properties of Vinyl Monomers

Monomer	d^{20}_4	n^{20}_D
Acrylonitrile	0.8055	1.3910
Methyl methacrylate	0.9340	1.4166
Vinyl acetate	0.9342	1.3958

TABLE 4

Copolymerization of Polyesters with Vinyl Monomers

System	Amt. starting components taken (in g-mole · 10^2)		Composition of copolymer (in g-mole · 10^2)			Composition of reaction mixture (in g-mole · 10^2)	
	polyester (taking amt. of reacted units into account)	of vinyl monomer	of polyester units: total	of polyester units: amt. of reacted units present	of vinyl monomer	of polyester units	of vinyl monomer
Poly(1,3-butylene glycol fumarate) – acrylonitrile	0.3328	2.6986	0.0251	0.0044	0.0537	0.3284	2.6443
	0.4502	1.3417	0.1436	0.0317	0.1008	0.4185	1.2409
	0.1161	3.2371	0.0469	0.0068	0.2054	0.1093	3.0317
Poly(1,3-butylene glycol fumarate) – methyl methacrylate	0.8810	1.6370	0.0310	0.0102	0.0468	0.8710	1.5902
	0.1700	3.3180	0.1040	0.0110	0.4680	0.1590	2.8500
	0.5030	1.0700	0.1660	0.0253	0.2000	0.4780	0.8700
	0.6830	0.9080	0.0614	0.0151	0.0670	0.6680	0.8410
Poly(1,3-butylene glycol fumarate) – vinyl acetate	0.7204	2.2540	0.3272	0.1077	0.1510	0.6127	2.1030
	0.7578	2.6290	0.1599	0.0621	0.0967	0.6949	2.5320
	0.7799	2.5690	0.6790	0.2702	0.4107	0.5090	2.1580
	0.5357	3.9530	0.1938	0.0987	0.1994	0.4372	3.7540
	0.6355	1.7640	0.2551	0.0943	0.1354	0.5407	1.6280
Poly(ethylene glycol fumarate) – vinyl acetate	0.8886	2.966	0.1079	0.0227	0.02568	0.8659	2.919
	0.7755	3.997	0.3329	0.09686	0.1066	0.6387	3.8993
	0.6145	4.1888	0.3122	0.0687	0.06426	0.5458	4.1246
	0.6570	2.205	0.4396	0.0873	0.1043	0.5697	2.101

A study of the acetone-soluble portion of the reaction products revealed that it is a mixture of the starting components (polyester and monomer).

The composition of the copolymers was calculated from the results of the elemental microanalysis for hydrogen, carbon and oxygen. For the calculation, we usually took the element with the greatest difference in amount in the polyester and the monomer.

To determine the amount of reacted polyester units we used the method based on the rule of additivity of the specific volumes and a definite shrinkage value for the monomers when polymerized [15].

The amount of reacted double bonds was determined using the formula: $X = \frac{a\delta_n + b\delta_{m_2} - \delta_c}{P_{m_2}}$, where X is the weight fraction of reacted polyester units in the copolymer, a and b are, respectively, the weight fractions of vinyl monomer and polyester in the copolymer, δ_n, δ_{m_2}, and δ_c are respectively, the specific volumes of the polymer of the vinyl monomer, polyester, and copolymer, and P_{m_2} is the specific shrinkage of the polyester unit.

The density of the copolymers was determined using a pycnometer. The copolymers prior to determining the density were pelleted at 150° and a pressure of 200 kg/cm^2.

The experimental data are given in Table 4, and these data were used in the graphical calculation of the copolymerization constants.

Copolymerization of poly (1,3-butylene glycol fumarate) with vinylcarbazole was run in toluene solution, in a nitrogen atmosphere, in the presence of benzoyl peroxide. Despite the long heating (up to 65 hours) at 100° and the addition of peroxide (up to 1%), the reaction products were completely soluble in acetone, which led us to conclude that vinylcarbazole does not copolymerize with poly (1,3-butylene glycol fumarate) under the given conditions.

SUMMARY

1. The peculiarities of the copolymerization of unsaturated polyesters with vinyl monomers were discussed.

2. A study was made of the copolymerization of poly (1,3-butylene glycol fumarate) with vinylcarbazole, acrylonitrile, methyl methacrylate, and vinyl acetate, and of poly (ethylene glycol fumarate) with vinyl acetate.

3. It was shown that acrylonitrile, the same as styrene, exhibits a lower activity in reaction with the radical of a polyester unit than in reaction with fumaric acid diesters, while vinyl carbazole is completely unreactive in copolymerization with polyesters, which apparently is due to steric factors. Vinyl acetate does not change its activity in these reactions.

4. The determined values of the copolymerization constants make it possible to calculate the conditions for obtaining copolymers of uniform composition from unsaturated polyesters and vinyl monomers.

LITERATURE CITED

[1] M. Gordon, B. M. Grieveson, and I. D. McMillan, J. Polymer Sci. 18, 497 (1955).

[2] B. Hayes and R. Hunter, Chem. and Ind. (London) 1957, 559.

[3] V. Wycherly, Chem. and Ind. (London) 1957, 431.

[4] W. Robertson and D. Shepherd, Chem. and Ind. 1958, 126.

[5] A. V. Tokarev and S. S. Spasskii, Zhur. Fiz. Khim. 23, 554 (1959).

[6] B. Hayes, W. Read, and L. Vaughan, Chem. and Ind. (London) 1957, 1162.

[7] L. B. Sokolov, Dissertation, Karpov Phys.-Chem. Inst. (1956).

[8] F. Leavitt, V. Stannett, and M. Szwarc, Chem. and Ind. (London) 1957, No. 28, 985.

[9] M. V. Vol'kenshtein, Structure and Physical Properties of Molecules [In Russian] (Moscow-Leningrad, Izd. AN SSSR, 1956), p. 138.

[10] L. I. Gindin, A. D. Abkin, and S. S. Medvedev, Zhur. Fiz. Khim. 21, 1269 (1947).

[11] S. N. Ushakov, S. P. Mitsengendler, and B. M. Polyatskina, Chemistry and Physical Chemistry of High-Molecular Compounds [In Russian] (Moscow, Izd. AN SSSR, 1952), p. 19.

[12] S. Feuer, T. Bockstahler, C. Brown, and I. Rosenthal, Ind. Eng. Chem. 46, 1643 (1954).

[13] Monograph: "Monomers" [Russian translation] (Moscow, IL, 1951), Vol. 1.

[14] Monograph: "Monomers" [Russian translation] (Moscow, IL, 1953), Vol. 2.

[15] S. S. Spasskii, A. I. Tarasov, and A. V. Tokarev, Zhur. Fiz. Khim. 33, 249 (1959).

[16] T. Alfrey Jr., J. J. Bohrer, and H. Mark, Copolymerization [Russian translation] (Moscow, IL, 1953).

COPOLYMERIZATION OF UNSATURATED POLYESTERS WITH VINYL MONOMERS

V. COPOLYMERIZATION OF POLY(1,3-BUTYLENE GLYCOL FUMARATE) WITH VINYL ALKYL ETHERS

S. S. Spasskii and A. I. Tarasov

Institute of Chemistry, Ural Branch of the Academy of Sciences, USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 257-263, January, 1960

Original article submitted July 30, 1958

In previous papers [1-4] we discussed the results of studying the copolymerization of unsaturated polyesters of different structure with those monomers for which the radical mechanism of polymerization is characteristic. For a better understanding of reactions of this type it seemed of interest to investigate the copolymerization of unsaturated polyesters with vinyl alkyl ethers, which, as is known, polymerize well by the ionic mechanism and poorly by the radical mechanism. However, in common with other monomers which polymerize under the influence of peroxide initiators (acrylic acid, methacrylic acid, their esters, etc.), the vinyl ethers are capable of giving copolymers. Here the radical of the vinyl ether reacts only with the "foreign" monomer. Proceeding from this fact, it could be assumed that the vinyl ethers when copolymerized with unsaturated polyesters will enter into the copolymer as single units.

In this paper we studied the effect of the structure of vinyl ethers on their relative activity when copolymerized with unsaturated polyesters.

TABLE 1

Copolymerization of Poly(1,3-butylene glycol fumarate) with Vinyl n-Propyl Ether

Amt. starting components taken (in g-mole · 10^2)		Composition of copolymer (in g-mole · 10^2)			Comp. of reaction mixture (in g-mole · 10^2)		Amt. of reacted fumaric units (in %)
of polyester (calc. on the reacted amt)	of vinyl ether	polyester		vinyl ether	polyester	vinyl ether	
		total	amount reacted				
0.3617	2.2209	0.1506	0.0746	0.0447	0.2871	2.1762	49
0.4631	1.1913	0.2786	0.1067	0.0770	0.3564	1.1143	38
0.4684	1.1025	0.2469	0.1034	0.0651	0.3650	1.0374	42
0.4436	0.6693	0.0812	0.0245	0.0114	0.4191	0.6579	30
0.5178	0.6598	0.1448	0.0518	0.0238	0.4660	0.6360	36
0.6809	0.5556	0.0884	0.0411	0.0172	0.6398	0.5384	46

For this purpose, we determined the constants for the copolymerization of poly(1,3-butylene glycol fumarate) with five vinyl ethers of different structure, calculated the composition diagrams of the copolymers, and studied the thermomechanical properties of the copolymers at different starting ratios of the components. To calculate the copolymerization constants we used the method described earlier [1, 2].

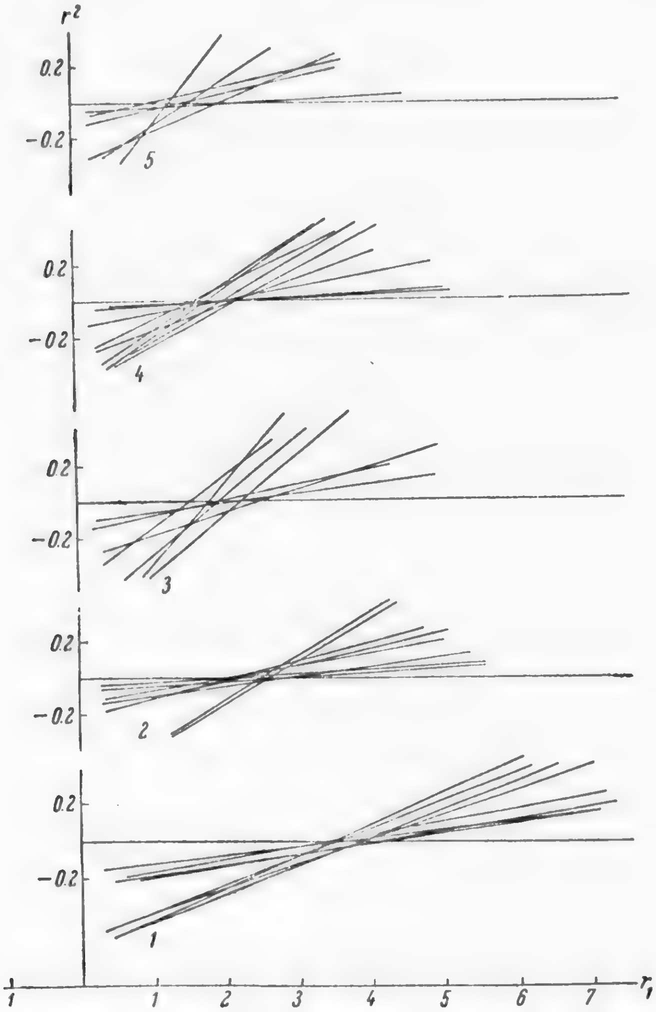


Fig. 1. Graphical calculation of constants for copolymerization of poly(1,3-butylene glycol fumarate) with vinyl alkyl ethers. 1) Vinyl isoamyl ether ($r_1 = 3.8 \pm 0.7$, $r_2 = 0$); 2) vinyl n-amyl ether ($r_1 = 2.7 \pm 0.7$, $r_2 = 0$); 3) vinyl isobutyl ether ($r_1 = 2.0 \pm 0.7$, $r_2 = 0$); 4) vinyl n-butyl ether ($r_1 = 1.8 \pm 0.5$, $r_2 = 0$); 5) vinyl n-propyl ether ($r_1 = 1.6 \pm 0.5$, $r_2 = 0$).

The results for the copolymerization of poly(1,3-butylene glycol fumarate) with vinyl n-propyl ether are given in Table 1. From the data in the table, it can be seen that the copolymer contains from 5 to 13% of the vinyl ether by weight. The amount of reacted fumaric units averages 40% (with a determination accuracy of ±10%). As the calculations reveal, such a large experimental error has a very small effect on the value of the copolymerization constants. Analogous results were also obtained for the other vinyl ethers.

The graphical calculation and values of the copolymerization constants are given in Fig. 1. The values of the constants indicate that vinyl ethers have a lower activity than the fumaric units of the polyester, and the radicals of the vinyl ethers hardly react with their own molecules. The structure of the vinyl ether has little effect on the relative activity in copolymerization with unsaturated polyesters.

TABLE 2

Comparison of Copolymerization Constants of Some Monomers With Diethyl Fumarate and Vinyl Ethers

Monomers		r_1	r_2
M_1	M_2		
Styrene [5]	Diethyl fumarate	0.30 ± 0.02	0.07 ± 0.007
Styrene [6]	Vinyl ethyl ether	90 ± 20	0
Vinyl acetate [7]	Diethyl fumarate	0.011 ± 0.001	0.444 ± 0.003
Vinyl acetate [8]	Vinyl ethyl ether	3.0 ± 0.1	0
Vinyl chloride [7]	Diethyl fumarate	0.12 ± 0.01	0.47 ± 0.05
Vinyl chloride [9]	Vinyl isobutyl ether	2.0 ± 0.2	0.02 ± 0.01

The obtained results coincide with the literature data on the copolymerization of vinyl ethers with other monomers.

If a comparison is made of the relative activity of vinyl ethers and fumaric acid diesters in copolymerization with a third monomer, then it is seen that also in this case the vinyl ethers are less active than the fumaric acid diesters (Table 2). As a result, the activity of vinyl ethers when they are copolymerized with polyesters and with fumaric acid diesters remains practically unchanged.

Using the equations of L. M. Gindin, A. D. Abkin, and S. S. Medvedev [10], and the method proposed by S. N. Ushakov, S. P. Mitsengendler, and B. M. Polyatskina [11], we calculated the integral composition of the copolymers. The calculation results are plotted in Figs. 2 and 3.

From the composition diagrams of the copolymers, it can be seen that all of the investigated systems approach the azeotrope only in the region of a very high concentration of the polyester. A rapid exhaustion of the polyester occurs at nonazeotropic ratios. Excess vinyl ether is incapable of forming polymeric molecules ($r_2 = 0$) and consequently remains in the block in the free state. The consumption of both components proceeds uniformly when the polyester : monomer ratio is in the vicinity of the azeotropic ratio of 9 : 1, and such a copolymer does not contain unreacted vinyl ether. This statement is supported by the thermomechanical investigations of the copolymers on the examples of vinyl n-butyl ether and vinyl isoamyl ether. The results of these investigations are shown in Figs. 4 and 5. From these graphs, it can be seen that all of the curves can be divided into two types: In one case, the start of deformation lies near the decomposition temperature, and in the other case, it is found at a relatively low temperature. Curves of the first type give copolymers with the ratios of the components close to the azeotrope. In harmony with the integral composition diagrams, the shape of these curves indicates that these copolymers have a uniform composition. The second type of curves give copolymers at ratios of the starting components different from the azeotrope. Deformation at comparatively low temperature and the smooth ascent of the curves can be due to the presence of unreacted vinyl alkyl ether in the copolymer, which gradually volatilizes when the specimen is heated.

The decomposition temperature of all of the copolymers, irrespective of the structure of the vinyl ethers and the starting ratio, lies between 260 and 280°.

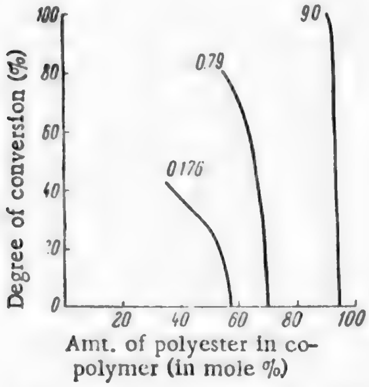


Fig. 2. Diagram of integral composition of copolymers from poly-(1,3-butylene glycol fumarate) and vinyl n-butyl ether. The numbers on the curves denote the number of moles of polyester per mole of vinyl ether in the starting mixture.

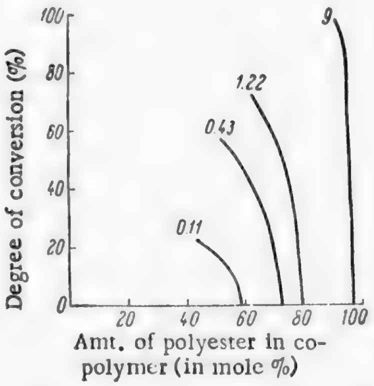


Fig. 3. Diagram of integral composition of copolymers from poly-(1,3-butylene glycol fumarate) and vinyl isoamyl ether. The numbers on the curves denote the number of moles of polyester per mole of vinyl ether in the starting mixture.

In contrast to the thermomechanical curves for the nonazeotropic copolymers from poly(1,3-butylene glycol fumarate) and vinyl ethers, it is characteristic that similar curves for the system poly(1,3-butylene glycol fumarate) — styrene do not have a smooth ascent, but instead a well-defined straight section (Fig. 6) [12]. This difference is evidently due to the fact that in the latter case the styrene, after exhaustion of the polyester, forms a polymeric chain.

As a result, the obtained copolymerization constants make it possible to explain the peculiarities in the behavior of vinyl alkyl ethers when reacted with unsaturated polyesters.

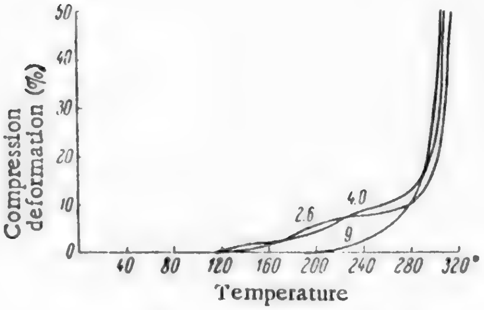


Fig. 4. Thermomechanical curves for copolymers from poly(1,3-butylene glycol fumarate) and vinyl n-butyl ether. The numbers on the curves denote the number of moles of polyester per mole of vinyl ether.

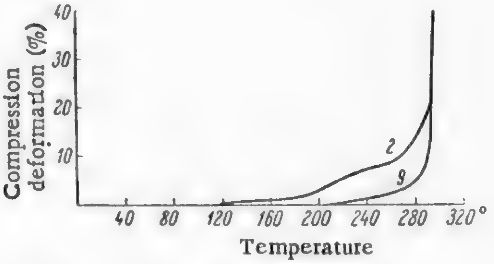


Fig. 5. Thermomechanical curves for copolymers from poly(1,3-butylene glycol fumarate) and vinyl isoamyl ether. The numbers on the curves denote the number of moles of polyester per mole of vinyl ether.

EXPERIMENTAL

Starting compounds. Maleic anhydride was purified by precipitation with methyl alcohol from a mixture of chloroform and carbon tetrachloride (1 : 1), and subsequent vacuum distillation. The product used for polycondensation had m. p. 53° and a maleic anhydride content of 99.8 %.

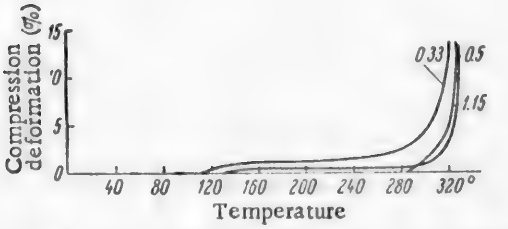


Fig. 6. Thermomechanical curves for copolymers from poly(1,3-butylene glycol fumarate) and styrene. The numbers on the curves denote the number of moles of polyester per mole of styrene in the starting mixture.

1,3-Butylene glycol was purified by vacuum distillation, after which it had d^{20}_4 1.0074 and $n^{20}D$ 1.4415.

Poly(1,3-butylene glycol fumarate) was obtained by the polycondensation of equimolar amounts of maleic anhydride and 1,3-butylene glycol in a nitrogen stream for 2 hours at 120°, and then at 190° until the desired acid number was obtained. The obtained specimen had an acid number of 56.13, a saponification number of 610.90, and d^{20}_4 1.2230.

The vinyl ethers were obtained by the A. E. Favorskii – M. F. Shostakovskii method [13]; their properties are given in Table 3.

TABLE 3

Properties of Vinyl Ethers

Ether	B. p.	d_4^{20}	n_D^{20}
Vinyl n-propyl	64—65°	0.7678	1.3920
Vinyl n-butyl	93	0.7792	1.4025
Vinyl isobutyl	82—83	0.7684	1.3960
Vinyl n-amyl	119.6—120.4	0.7870	1.4190
Vinyl isoamyl	111.5—112.0	0.7824	1.4080

The benzoyl peroxide was purified by precipitation with methyl alcohol from chloroform solution.

Ionic polymerization of vinyl ethers. In a 150-ml three-necked flask fitted with a reflux condenser, thermometer, and stirrer, was placed 30-40 ml of vinyl alkyl ether, and after heating to a temperature near the boiling point of the ether, 2-3 drops of a 2% ferric chloride solution in the alcohol corresponding to the ether was added. Here the temperature rose to 110-120°, and the viscosity of the ether increased greatly. The polymers from vinyl n-propyl ether and vinyl n-butyl ether were rid of unreacted ether by heating in vacuo (5-6 mm) at 100-120°. The other polymers were precipitated from benzene solution with methanol, and then were dried in vacuo to constant weight. The densities of the polymers obtained from the vinyl alkyl ethers are given in Table 4.

Copolymerization procedure. The weighed amount of polyester in vinyl ether solution was placed in a tared ampule with a drawn-out end, the ampule was weighed, cooled in liquid nitrogen, filled with oxygen-free nitrogen, and sealed.

The amount of benzoyl peroxide added to the solution ranged from 0.01 to 0.1% by weight. The copolymerizations were run in a thermostat at 60 ± 0.5°. The reaction time was taken such as to give different degrees of polymerization for each ratio of the components. The obtained tridimensional polymer was washed with acetone to remove unreacted polyester and vinyl ether until no more polyester was present (addition of water to the solvent failed to give a turbidity on long standing). The washed polymer was dried in vacuo at 70-80° to constant weight. The degree of conversion was determined as the ratio of the amount of obtained

polymer to the original weight of the mixture. Analysis of the acetone-soluble portion for acid number and saponification number revealed it to be unreacted polyester.

TABLE 4

Density of Polymers from Vinyl Ethers

Polymer from ether	d^{20}_4
Vinyl n-propyl	0.9418
Vinyl n-butyl	0.9322
Vinyl isobutyl	0.9010
Vinyl n-amyl	0.9151
Vinyl isoamyl	0.9117

The composition of the tridimensional polymers was calculated from the elemental microanalysis data for oxygen. The density was determined by the pycnometer method using n-butyl alcohol as the auxiliary liquid. Prior to determination, the copolymers were pelleted at a pressure of 150 kg/cm^2 and a temperature of 180-200°.

The V. A. Kargin method [14, 15] was used to investigate the thermomechanical properties of the copolymers. The curves, plotted in the coordinates percent compression deformation vs. temperature, were obtained using the apparatus designed by D. L. Tsetlin, D. I. Gavrilov, N. A. Velikovskaya, and V. V. Kochkin [16]. The testing was done with a load of 40 kg/cm^2.

The test samples were obtained by block copolymerization in ampules, in the presence of 0.2% benzoyl peroxide, for 6-8 hours at 60°, and at 15-20 hours at 80° in order to obtain more complete hardening. Complete hardening occurred in this length of time. The copolymers that were kept at 80° for 60 hours gave the same type of plot as those held for 15-20 hours. The specimens cut out of the blocks had a diameter of 9 mm and a thickness of 3.5 mm.

SUMMARY

1. The copolymerization of poly(1,3-butylene glycol fumarate) with five different vinyl ethers was examined. It was shown that up to a conversion degree of 15-20% the copolymer still contains about 60% of unreacted double bonds of the polyester. The copolymerization constants were determined and it was established that the activity of vinyl ethers with respect to the fumaric linkage is practically independent of their structure.

2. A copolymer of uniform composition is formed if the ratio of polyester to vinyl ether is taken not less than 9:1.

3. The validity of the found copolymerization constants was confirmed by investigating the thermomechanical properties of the copolymers obtained from poly(1,3-butylene glycol fumarate) and the vinyl ethers.

LITERATURE CITED

[1] S. S. Spasskii, A. I. Tarasov, and A. V. Tokarev, Zhur. Fiz. Khim. 33, 249 (1959).

[2] A. V. Tokarev and S. S. Spasskii, Zhur. Fiz. Khim. 33, 554 (1959).

[3] S. S. Spasskii, A. V. Tokarev, M. A. Mikhailova, M. E. Mat'kova, and T. V. Molchanova, Zhur. Obshchei Khim. 30, 250 (1960).*

[4] S. S. Spasskii, M. A. Mikhailova, A. I. Tarasov, T. V. Molchanova, and M. E. Mat'kova, Zhur. Fiz. Khim. 33, 1449 (1959).

[5] F. M. Lewis, C. Walling, W. Cummings, E. R. Briggs, and F. R. Mayo, J. Am. Chem. Soc. 70, 1519 (1948).

[6] F. M. Lewis, C. Walling, W. Cummings, E. R. Briggs, and W. J. Wenisch, J. Am. Chem. Soc. 70, 1527 (1948).

[7] F. M. Lewis and F. R. Mayo, J. Am. Chem. Soc. 70, 1533 (1948).

[8] F. R. Mayo, C. Walling, F. M. Lewis, and W. F. Hulse, J. Am. Chem. Soc. 70, 1523 (1948).

[9] E. C. Chapin, G. E. Ham, and C. L. Mills, J. Polymer Sci. 4, 597 (1949).

* Original Russian pagination. See C. B. translation.

[10] L. M. Gindin, A. D. Abkin, and S. S. Medvedev, Zhur. Fiz. Khim. 21, 1269 (1947).

[11] S. N. Ushakov, S. P. Mitsengendler, and B. M. Polyatskina, Monograph: "Chemistry and Physical Chemistry of High-Molecular Compounds" [In Russian] (Izd. AN SSSR, 1952), p. 19.

[12] A. V. Tokarev and S. S. Spasskii, Collection of Works of Institute of Metallurgy, Ural Branch, Acad. Sci. USSR [In Russian] 4, 127 (1958).

[13] A. E. Favorskii and M. F. Shostakovskii, Zhur. Obshchei Khim. 13, 1 (1943).

[14] V. A. Kargin and T. I. Sogolova, Zhur. Fiz. Khim. 23, 530 (1949).

[15] V. A. Kargin and M. N. Shteiding, Khim. Prom. 3, 64 (1955).

[16] V. L. Tsetlin, V. I. Gavrilov, N. A. Velikovskaya, and V. V. Kochkin, Zavodskaya Lab. 31, 352 (1956).

SYNTHESIS AND POLYCONDENSATION OF p-AMINOETHYLPHENYLALKANECARBOXYLIC ACIDS

M. N. Bogdanov, G. I. Kudryavtsev, and I. A. Spirina

All-Union Scientific Research Institute of Artificial Fibers

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 263-267, January, 1960

Original article submitted January 2, 1959

p-(ω-Aminoalkyl)phenylalkanecarboxylic acids

$$NH_2(CH_2)_nC_6H_4(CH_2)_mCOOH$$

are of interest for obtaining polyamides that are suitable for the formation of heat-stable synthetic fibers. The synthesis and polycondensation of p-aminomethylphenylalkanecarboxylic acids to yield high-molecular polyamides had been described by us earlier [1]. Continuing our investigation in the present paper, we synthesized a number of new amino acids belonging to this series, namely, some p-aminoethylphenylalkanecarboxylic acids, and obtained the corresponding polyamides from them.

Synthesis of the previously unknown p-aminoethylphenylalkanecarboxylic acids was accomplished by the following scheme

$$C_6H_5(CH_2)_nCOOH \longrightarrow ClCH_2C_6H_4(CH_2)_nCOOH \longrightarrow CNCH_2C_6H_4(CH_2)_nCOOH \longrightarrow$$
$$\longrightarrow HCl \cdot NH_2(CH_2)_2C_6H_4(CH_2)_nCOOR \longrightarrow NH_2(CH_2)_2C_6H_4(CH_2)_nCOOH.$$

For the chloromethylation of the phenylalkanecarboxylic acids we used the earlier described method [2], with the only difference that instead of formalin we took a suspension of paraform in concentrated hydrochloric acid. The reaction goes much faster in this case. In the cyanation of the p-chloromethylphenylalkanecarboxylic acids we used a large excess of potassium cyanide on the assumption that a part of the potassium cyanide is consumed to form the potassium salt of the carboxylic acid. Purification of the p-cyanomethylphenylalkanecarboxylic acids by vacuum distillation is impractical due to their tendency to convert to linear and cyclic imido compounds [3].

Hydrogenation of the p-cyanomethylphenylalkanecarboxylic acids using the usual procedure for the catalytic reduction of nitriles (in alcoholic ammonia solution using Raney nickel catalyst) is unsuccessful, since the nickel reacts with the carboxylic acid. For this reason, the hydrogenation was run in an aqueous mixture of ammonia and KOH (in the same manner as cyanoacetic acid is hydrogenated to β-alanine) [4].

Because of impurities, we were unable to isolate the amino acids as such from the hydrogenation products of the nitriles. For this reason, the amino acids were isolated from the hydrogenation products as the hydrochlorides of the methyl esters. In the case of obtaining p-aminoethylphenylacetic acid the synthesis was accomplished through the hydrochloride of the ethyl ester, since the free methyl ester of this acid is readily soluble in water and consequently is obtained in poor yield. The amino acids were isolated from the hydrochlorides of their esters by decomposing the latter with aqueous ammonia, followed by saponification of the free esters with barium hydroxide.

In this paper we synthesized p-aminoethylphenylacetic (I), p-aminoethylphenylpropionic (II), p-aminoethylphenylbutyric (III) and p-aminoethylphenylvaleric (IV) acids. These amino acids, the same as the p-aminomethylphenylalkanecarboxylic acids, are converted into high-molecular polyamides not only by polycondensation in the liquid phase (in a melt), but also in the solid phase.

The polyamides obtained by the melt polycondensation of amino acids (I), (III), and (IV) are tough, white, hornlike materials, from which it is possible to spin threads that can be cold-drawn. The polyamide from amino acid (II) melts with decomposition and can be obtained with a high molecular weight only by polycondensation in the solid phase; it is soluble only in concentrated sulfuric acid, in which it forms quite concentrated viscous solutions. Despite the larger number of methylene groups, the polyamide from (II) melts some 100° above the polyamide from (I), which indicates the important role played by the structural symmetry of the polymer unit. An increase in the melting point in going from the polyamide from (III) to the polyamide from (IV) can probably be explained by an increase in the intramolecular reaction forces due to the fact that each chain, located between the benzene rings and the amino groups, contains an even number of methylene groups.

EXPERIMENTAL

The amino acids were all obtained by the same technique, for which reason we will describe only the synthesis of p-aminoethylphenylvaleric acid. The data on the other amino acids and intermediate compounds are summarized in Tables 1-4.

TABLE 1

Cyanocarboxylic Acids $CNCH_2C_6H_4(CH_2)_nCOOH$

Substance No.	Value of n	Yield (in %)	M. p.	Content (in %)					
				found			calculated		
				C	H	N	C	H	N
(I)	1	50	120.0–121.5°	68.80, 68.35	5.15, 5.01	7.91, 7.79	68.56	5.18	7.99
(II)	2	42	107.0–108.0	70.32, 70.19	5.95, 5.79	7.38, 7.62	69.83	5.86	7.40
(III)	3	57	86.5–87.0	70.82, 70.98	6.63, 6.57	6.78, 6.58	70.95	6.40	6.88
(IV)	4	54	63.5–65.0	71.61, 71.68	6.87, 6.95	6.43, 6.46	71.90	6.63	6.44

p-Cyanomethylphenylvaleric acid. A suspension of 50 g of potassium cyanide in 50 ml of water was gently heated with stirring until most of the salt had dissolved. Then 100 ml of ethanol and 50 g of p-chloromethylphenylvaleric acid were added and the mixture was cautiously heated under reflux for 1.5 hours. The obtained black solution was vacuum distilled until 85 ml of liquid had distilled, and the residue was treated with 300 ml of water. The stirred solution was acidified with concentrated hydrochloric acid and cooled in ice. The precipitate was filtered, washed with water, dried, and extracted twice with 40-ml portions of hot benzene. The combined benzene extracts were filtered and the benzene was distilled off. The residue (cyanocarboxylic acid) was purified by extraction with hot 25% aqueous methanol (240 ml), and the extracts were cooled in ice. After ten such operations, we obtained 27.3 g (54%) of the nitrile with m. p. 58.0-63.5°, which was suitable for hydrogenation. To obtain the analytically pure specimen(with m. p. 63.5-65.0°) the product was digested with hot petroleum ether and the extract was cooled.

Hydrochloride of methyl ester of p-aminoethylphenylvaleric acid. Thirty grams of p-cyanomethylphenylvaleric acid was dissolved in a mixture of 260 ml of 26% ammonia and 72 ml of 15% KOH. The hydrogenation was run at room temperature in a 1-liter rotated,horizontal autoclave in the presence of 9 ml of an aqueous suspension of Raney nickel catalyst. The initial hydrogen pressure was 98 atmos, the final pressure was 80 atmos, and the reaction time was 4.5 hours. The catalyst was filtered, and the solution was concentrated to a volume of 85 ml by distilling off the water in vacuo, and filtered. The filtrate was acidified with 40 ml of concentrated

hydrochloric acid and the obtained suspension was evaporated to dryness. The residue was digested 4 times with 40-ml portions of hot methanol. The extracts were filtered from mineral salt, combined, and saturated with hydrogen chloride. The obtained precipitate was filtered, the filtrate was stirred with 350 ml of ether, and the obtained second crop was combined with the first and the whole washed with ether. The substance was then dissolved in 95 ml of hot methanol, the solution boiled with activated carbon, filtered, and mixed with 300 ml of ether. We obtained 19.5 g (65%) of the hydrochloride, with m. p. 172.5-175.0°.

TABLE 2

Hydrochlorides of Esters of p-Aminoethylphenylalkanecarboxylic Acids $HCl \cdot NH_2(CH_2)_2C_6H_4(CH_2)_nCOOR$*

Substance No.	Value of n	Yield (in %)	M. p.	Content (in %)			
				found		calculated	
				N	Cl	N	Cl
(I)	1	51	172.5–173.5°	5.59, 5.52	14.55, 14.54	5.73	14.57
(II)	2	62	214.5–215.5	5.61, 5.73	14.58, 14.68	5.73	14.57
(III)	3	56	172.0–173.0	5.64, 5.50	13.72, 13.70	5.46	13.77
(IV)	4	65	172.5–175.0	5.14, 5.03	13.04, 13.05	5.15	13.03

* (II) - (IV) are the hydrochlorides of the methyl esters, and (I) is the hydrochloride of the ethyl ester.

TABLE 3

p-Aminoethylphenylalkanecarboxylic Acids $NH_2(CH_2)_2C_6H_4(CH_2)_nCOOH$

Substance No.	Value of n	Yield (in %)	Melting point *	Content (in %)					
				found			calculated		
				C	H	N	C	H	N
(I)	1	53	—	67.29, 67.24	7.17, 7.21	7.96, 7.68	67.02	7.37	7.82
(II)	2	68**	—	68.44, 68.06	8.12, 7.84	7.24, 7.18	68.37	7.82	7.24
(III)	3	50	—	69.56, 69.70	8.32, 8.15	6.95, 7.00	69.62	8.20	6.75
(IV)	4	53	199.0–199.5°	70.72, 70.49	8.47, 8.30	6.32, 6.27	70.60	8.59	6.33

* The melting points of amino acids (I) - (III) lie above the initial polycondensation temperatures in the solid phase, for which reason an accurate determination of these constants is impossible.

** This acid is quite soluble in aqueous alcohol solutions, for which reason it was recrystallized from aqueous acetone solution.

p-Aminoethylphenylvaleric acid. Eighteen grams of powdered p-aminoethylphenylvaleric acid methyl ester hydrochloride was shaken in a separatory funnel with 47 ml of 26% aqueous ammonia until all of the solid had disappeared.* The obtained emulsion of free amino acid ester in water was extracted twice with 75-ml

* To obtain p-aminoethylphenylpropionic acid the hydrochloride was digested with hot aqueous ammonia, the resulting emulsion was cooled, and the crystalline amino acid ester was filtered and washed with water.

TABLE 4

Properties of Polyamides from p-Aminoalkylphenylalkanecarboxylic Acids

Substance No.	Formula of amino acid	Polycondensation conditions		Properties of polyamides				
		temp.	time (in min)	character of product	m. p.	solution viscosity*	solubility in aromatic alcohols	ability to form fibers from melt
(I)	$NH_2(CH_2)_2C_6H_4CH_2COOH$	290°/305	90/30	White, hornlike, tough	279—283°	0.60/0.45	Soluble	Tough fibers
(II)	$NH_2(CH_2)_2C_6H_4(CH_2)_2COOH$	310/320	120/60—60**	White fused granules	375—382 (dec.)	2.42/3.17	Soluble only in conc. H_2SO_4	Weak fibers
(III)	$NH_2(CH_2)_2C_6H_4(CH_2)_3COOH$	200/300	1020/60	White powder / White, hornlike, tough	222—224	1.16/0.56	Soluble	Tough fibers
(IV)	$NH_2(CH_2)_2C_6H_4(CH_2)_4COOH$	265/290	120/60	White, fused granules / White, hornlike, tough	273—275	2.10/0.92	Soluble	Tough fibers

* For polyamides (I), (III), and (IV) we determined the specific viscosity of a 0.5% solution of the polyamide in tricresol, and for polyamide (II) the relative viscosity of a 1% solution of the polymer in concentrated H_2SO_4.

** Heating in a vacuum of 2 mm.

portions of ether, the combined ether extract was washed twice with 50-ml portions of water, and the solvent was vacuum distilled in a warm water bath. The residue was dissolved in 70 ml of 50% aqueous methanol, mixed with 11 g of barium hydroxide, and the mixture heated under reflux for 1 hour. The suspension after cooling was saturated with carbon dioxide until weakly alkaline to litmus. The precipitate was filtered and then digested twice with 50-ml portions of hot aqueous ammonia. The combined ammoniacal extracts and filtrate was evaporated to dryness. The residue was dissolved in 100 ml of hot water, the solution filtered, concentrated to incipient crystallization, and mixed with 200 ml of acetone. The obtained precipitate was dissolved in 75 ml of boiling water, the solution mixed with 200 ml of methanol, and the whole allowed to stand for 2 days. We obtained 9.6 g (53%) of the amino acid with m. p. 199.0-199.5°.

Polycondensation of the amino acids was run in test tubes placed inside of glass sleeves and heated in a Wood's metal bath, through which a current of pure nitrogen was circulated. The results of some of the polycondensation experiments are summarized in Table 4.

SUMMARY

The previously unknown p-aminoethylphenylacetic, p-aminoethylphenylpropionic, p-aminoethylphenylbutyric and p-aminoethylphenylvaleric acids were synthesized. The indicated amino acids were converted to the polyamides, containing benzene rings in the chain, and some of their properties were investigated.

LITERATURE CITED

[1] M. N. Bogdanov and G. I. Kudryavtsev, Zhur. Obshchei Khim. 29, 986 (1959).*

[2] M. N. Bogdanov, Zhur. Obshchei Khim. 28, 1621 (1958).*

[3] E. N. Zil'berman, Zhur. Obshchei Khim. 25, 2127 (1955).*

[4] P. Ruggli and A. Businger, Helv. Chim. Acta 25, 39 (1942).

* Original Russian pagination. See C. B. translation.

ESTERS OF AMINOBENZOYLAMIDOPHOSPHORIC ACIDS

A. V. Kirsanov and N. G. Feshchenko

Institute of Organic Chemistry, Academy of Sciences of the Ukrainian SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 267-270, January, 1960

Original article submitted January 19, 1959

Aminobenzoic acids and their derivatives have great physiological importance, for which reason it seemed of interest to prepare some esters of aminobenzoylamidophosphoric acids in order to study their physiological properties.

To synthesize the aminobenzoylamidophosphoric acid esters we selected the following route:

$$NO_2C_6H_4CONH_2 \xrightarrow{+PCl_5} NO_2C_6H_4CON{=}PCl_3\,[1] \xrightarrow{+HCOOH}$$
$$\rightarrow NO_2C_6H_4CONHPOCl_2\,[1] \xrightarrow{+2ROH} NO_2C_6H_4CONHPO(OR)_2\,[2] \xrightarrow[Pt]{+H_2}$$
$$\rightarrow NH_2C_6H_4CONHPO(OR)_2.$$

TABLE 1

Dimethyl and Diphenyl Esters of Aminobenzoylamidophosphoric Acids of Type $NH_2C_6H_4CONHPO(OR)_2$

Position of NH_2	R	Yield (%)	Recrystallization solvent and appearance	M. p.	Found N (%)	Empirical formula	Calculated N (%)	Solubility*				
								water	alcohol	C_6H_6	CCl_4	acetone
o	CH_3	82	Water, needles	149–152°	11.49, 11.60	$C_9H_{13}O_4N_2P$	11.48	+	++	−	=	++
m	CH_3	70	Alcohol, prisms	125–127	11.24, 11.07	$C_9H_{13}O_4N_2P$	11.48	++	++	=	=	−
p	CH_3	84	Alcohol, prisms	169–170	11.32, 11.23	$C_9H_{13}O_4N_2P$	11.48	−	+	=	=	−
o	C_6H_5	91	70% alcohol needles	142–144	7.52, 7.42	$C_{19}H_{17}O_4N_2P$	7.61	−	+	+	−	+
m	C_6H_5	91	70% alcohol, needles	167–169	7.45, 7.43	$C_{19}H_{17}O_4N_2P$	7.61	−	+	−	−	++
p	C_6H_5	97	Benzene or alcohol, prisms	163–164	7.52, 7.42	$C_{19}H_{17}O_4N_2P$	7.61	=	+	−	=	++

* =) not soluble at the boiling point; −) difficultly soluble at the boiling point; +) difficultly soluble at 20° and readily soluble at the boiling point; ++) readily soluble at 20°. All of the compounds are insoluble in boiling ether and petroleum ether.

The dimethyl and diphenyl esters of the nitrobenzoylamidophosphoric acids were obtained by the earlier described procedures [1, 2], while their reduction to the esters of the aminobenzoylamidophosphoric acids was accomplished in alcohol solution using molecular hydrogen and platinum catalyst (see [3]).

The dimethyl and diphenyl esters of the aminobenzoylamidophosphoric acids (Table 1) are colorless crystalline compounds of amphoteric character, dissolving in dilute aqueous solutions of alkalies and acids with the formation of salts, and separating from such solutions in unchanged form on neutralization. In aqueous alcohol solutions they titrate with alkalies, using phenolphthalein as indicator, to approximately half an equivalent.

To characterize the esters we used the Schotten–Baumann technique to prepare the benzoyl derivatives, which are (Table 2) comparatively high-melting crystalline compounds of acid character, titrating in aqueous alcohol solutions in the presence of phenolphthalein as monobasic acids.

TABLE 2

Benzoyl Derivatives of Dimethyl and Diphenyl Esters of Aminobenzoylamidophosphoric Acids of Type $C_6H_5CONHC_6H_4CONHPO(OR)_2$

Position of C_6H_5CONH	R	Yield (%)	Appearance	M. p.	Found N (%)	Empirical formula	Calculated N (%)	Solubility* alcohol	petroleum ether	C_6H_6	CCl_4	acetone
o	CH_3	98	Needles	162–164°	8.07, 8.08	$C_{16}H_{17}O_5N_2P$	8.04	+	+	+	=	++
m	CH_3	73	Prisms	165–166	8.06, 8.09	$C_{16}H_{17}O_5N_2P$	8.04	—	=	=	=	—
p	CH_3	94	Needles	186–188	8.14, 8.08	$C_{16}H_{17}O_5N_2P$	8.04	+	=	=	=	+
o	C_6H_5	96	Needles	171–173	6.22, 6.33	$C_{26}H_{21}O_5N_2P$	5.93	+	=	+	—	++
m	C_6H_5	86	Fine needles	182–184	5.94, 5.91	$C_{26}H_{21}O_5N_2P$	5.93	—	=	=	=	—
p	C_6H_5	93	Fine crystalline powder	193–195	6.10, 6.04	$C_{26}H_{21}O_5N_2P$	5.93	—	=	=	=	—

* All of the compounds are insoluble in boiling water and ether, readily soluble in boiling dioxane, and difficultly soluble in cold dioxane.

EXPERIMENTAL

Dimethyl and diphenyl esters of aminobenzoylamidophosphoric acids. For the reduction, 0.01 g-mole of the nitrobenzoylamidophosphoric acid diester was dissolved with heating in 50-70 ml of 96% alcohol (the same amount of dioxane was used in the case of the diphenyl esters of m- and p-nitrobenzoylamidophosphoric acids) and then with vigorous stirring the solution was cooled in ice water in order to obtain as fine crystals of the compound as possible. Then 0.25-0.30 g-mole of Adams platinum oxide was added and the reduction accomplished with shaking, using hydrogen at a pressure 100 mm in excess of atmospheric. The hydrogen absorption went with noticeable warming-up of the solution. The major portion of the hydrogen was absorbed in 1-2 hours, and in some cases several days were required to absorb the last 100-150 ml of hydrogen. The starting compound gradually went into solution as the reduction progressed, and then the reaction product began to deposit as a fine crystalline precipitate. When the calculated amount of hydrogen had been absorbed, the hydrogenation mixture was treated with an equal amount of alcohol (or dioxane) to dissolve all of the reaction product, after which the platinum was filtered and the filtrate was evaporated in vacuo. Another procedure that can be used here is to add 10 ml of aqueous 1 N NaOH solution to the reaction mixture to dissolve the reduction product,

filter off the platinum, and then precipitate the aminobenzoylamidophosphoric acid diester in the filtrate by the addition of 5.0 ml of 2 N hydrochloric acid solution. The melting points, yields, analytical data, solubility, and crystalline appearance of the synthesized compounds are given in Table 1.

Benzoyl derivatives of dimethyl and diphenyl esters of aminobenzoylamidophosphoric acids. A solution of 0.003 g-mole of aminobenzoylamidophosphoric acid diester in 3 ml of 1 N NaOH solution was treated with 3 ml of 2 N sodium carbonate solution and 0.0045 g-mole of benzoyl chloride, and then the mixture was shaken vigorously until the odor of benzoyl chloride had disappeared. The liquid became warm, and the sodium salt of the benzoyl derivative deposited as a viscous oil. The mixture was then treated with 5 N hydrochloric acid solution until weakly acid to Congo and stirred vigorously. The sodium salt converted to the free benzoyl derivative, which at first was a viscous oil that soon crystallized. To remove benzoic acid the product was digested 3 times with small portions of boiling water and then recrystallized from alcohol. The analytical data, melting points, yields, solubility, and crystalline appearance of the benzoyl derivatives are given in Table 2.

SUMMARY

Reduction of the diesters of nitrobenzoylamidophosphoric acids with molecular hydrogen in the presence of platinum gave the diesters of aminobenzoylamidophosphoric acids.

LITERATURE CITED

[1] A. V. Kirsanov, Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk 1954, 646;* A. V. Kirsanov and R. G. Makitra, Zhur. Obshchei Khim. 26, 905, 907 (1956).*

[2] A. V. Kirsanov, Chemistry and Use of Organophosphorus Compounds [In Russian] (Izd. AN SSSR, 1957), p. 99; A. V. Kirsanov and R. G. Makitra, Zhur. Obshchei Khim. 28, 35 (1958).*

[3] A. V. Kirsanov and N. G. Feshchenko, Zhur. Obshchei Khim. 28, 1049 (1958).*

* Original Russian pagination. See C. B. translation.

POLYMETHYLENE CYCLES

XXXIII. REACTION OF DIBENZOSUBERAN-6,7-DIONE WITH HYDRAZINE

N. A. Domnin and R. Ch. Kolinskii

Leningrad State University

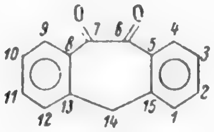
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 270-275, January, 1960

Original article submitted December 30, 1958

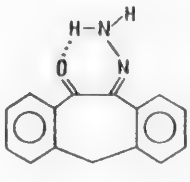
In a series of papers on the reaction of hydrazine and dimethylhydrazine with cyclic diketones one of us [1] investigated the five- and six-membered cyclic 1,2-, 1,3- and 1,4-diketones. The reaction of eight- and twelve-membered cyclic 1,2-diketones with hydrazine was investigated by Blomquist [2] and by Prelog [3]. The reaction of hydrazine with a seven-membered cyclic 1,2-diketone has remained unstudied up to now.

On the other hand, all of the enumerated studies had as their goal the problem of determining the distribution of the unsaturated bonds in polymethylene cycles. In particular, the existence of polymethylene rings containing the triple bond was shown conclusively. It was established that, beginning with the eight-membered ring and higher, cycles containing the triple bond are capable of existence, but the question of whether a seven-membered ring containing the triple bond is capable of existence remained unanswered and was not studied experimentally. Even earlier, we had shown [4] that 1,2-cycloheptadiene is formed when the triple bond is introduced into a seven-membered ring by the A. E. Favorskii method. The most probable explanation for its formation is isomeric rearrangement of the intermediately formed cycloheptyne with a shift of hydrogen atoms from adjacent methylene groups to the triple bond. In order to eliminate the possibility of such an isomerization, we proposed [5] to synthesize the cycloheptyne from a cyclic system in which the hydrogen atoms of the adjacent methylene groups are replaced by either methyl or phenyl radicals.

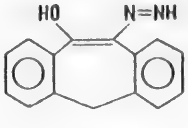
In this paper we selected dibenzosuberan-6,7-dione or tricyclo-[15-5, 13-8]-pentadecadiaren-1,8-dione-6,7 (I) [6] as the study topic.



(I)



(II)



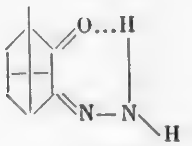
(IIa)

Diketone (I) was first obtained by Rigaudy and Nedelec [7]; however, only the synthesis scheme and physical constants of the compounds are given in their paper, and nothing is said about the reaction conditions. Consequently, the complete synthesis of the diketone is described in our experimental section. The reaction of hydrazine hydrate with diketone (I) in alcohol solution gave monohydrazone (II), the structure of which was confirmed by elemental analysis and its hydrolysis with hydrochloric acid to regenerate diketone (I).

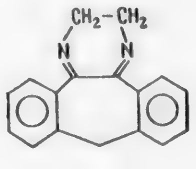
Dibenzosuberan-6,7-dione monohydrazone (II) is a yellow compound and has m. p. 131-132°, i.e., its m. p. is lower than the diketone (I) itself. In this respect it differs from benzil monohydrazone, which exists as white crystals with m. p. 150°, i.e., with a higher melting point than that of the corresponding diketone, namely benzil. At first we assumed it was possible for the tautomeric diazohydride form (IIa) to exist by analogy with the tautomerism of quinone phenylhydrazones. But monohydrazone (II) does not give a reaction for enolic hydroxyl group, since it is insoluble in alkali and fails to react with an ether solution of diazomethane, which refutes such an assumption.

Attempts to prepare the dibenzosuberan-6,7-dione dihydrazone proved unsuccessful. We reacted hydrazine hydrate or anhydrous hydrazine with diketone (I) or monohydrazone (II) in alcohol solution, and also in glacial acetic acid solution, heating for a long time. Here the reaction was accompanied by much tar formation. Two crystalline compounds were isolated, which from their nitrogen content analyzed close to the monohydrazone. We were unable to establish the structure of these compounds. In attempting to obtain the dihydrazone by the van Alphen procedure [9] we established the formation of the corresponding dihydropyrazine (IV), which remained unchanged when reacted with hydrazine.

Such properties for monohydrazone (II) can be explained if it is assumed that it has a syn-hydrazone structure, which is capable of conjugated hydrogen bonding (chelate ring). In support of such a hypothesis is the similarity in the properties of monohydrazone (II) and camphorquinone β-monohydrazone (III). Compound (III) is also colored yellow, melts at 102°, i.e., lower than camphorquinone (195°), and does not give a dihydrazone. The syn-configuration of monohydrazone (III) was established by Han-Ching Yuan [8].

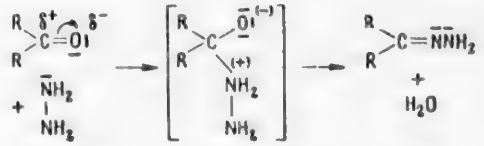


(III)



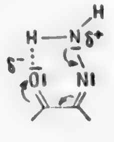
(IV)

To explain deactivation of the carbonyl group in monohydrazones (II) and (III) we must consider the reaction mechanism for the formation of hydrazones.



The first stage of the reaction consists of the addition of hydrazine through the free pair of electrons of the amine group to the positive center of the polarized double bond of the ketone group. Cleavage of water and the formation of the C=N double bond occurs in the second stage. The polarization of the carbonyl group, i.e., the magnitude of the positive charge on the carbon atom has very great significance for all of the reactions.

Monohydrazones (II) and (III) have a planar or nearly planar arrangement of the ketone and hydrazone groups. This creates favorable conditions for conjugation of the double bonds and the free pair of electrons on the nitrogen atom in the β-position to the ketone group. As a result of conjugation the positive charge on the carbon atom of the ketone group is shifted toward the nitrogen atom in the β-position. The absence of a positive charge on the carbon atom deactivates the ketone group and makes the addition of a second amine molecule impossible.



Reaction of diketone (I) with dimethylhydrazine led to an unexpected result. We obtained a crystalline compound with m. p. 245-247°, which was insoluble in the common organic solvents, rendering its purification difficult. This compound is apparently a condensation product of several molecules of diketone (I), since it does not contain nitrogen. We have been unable to establish the structure of this compound as yet.

EXPERIMENTAL*

o-Benzoylbenzoic acid was prepared by the Friedel-Crafts reaction from phthalic anhydride and benzene using anhydrous $AlCl_3$ as the catalyst. M. p. 125-128°. Yield 95% [10].

o-Benzylbenzoic acid was prepared by the Barnett method [11] by the reduction of o-benzoylbenzoic acid with zinc and ammonia in the presence of copper sulfate as the catalyst. M. p. 116-118°. Yield 75%.

Acid chloride. In a 125-ml Bunsen flask with a calcium chloride tube attached to the side arm was placed 25 ml of dry ether, containing 2 drops of pyridine. The cooled mixture was treated with 10 ml (about 0.15 mole) of thionyl chloride and 20 g (0.1 mole) of o-benzylbenzoic acid. The flask was stoppered and placed under a hood for 30 minutes at room temperature, with periodic shaking. Then the mixture was heated for 10 minutes on the water bath to complete the reaction, the calcium chloride removed, and vacuum applied gradually to remove the ether and excess thionyl chloride. Here the temperature should not exceed 40°. After keeping under complete vacuum for several minutes, 5 ml of dry benzene was added, and the removal of the solvent by distillation was repeated. The oily acid chloride remaining in the flask weighed 20-23 g. Yield 95-98%.

o-Benzyl-ω-diazoacetophenone. To an ether solution, containing 9.5-9.8 g (0.23 mole) of diazomethane [12], was added in drops a solution of 22 g (0.1 mole) of o-benzylbenzoyl chloride in 100 ml of ether. The flask was protected with a calcium chloride tube and then allowed to stand overnight at room temperature. The ether was vacuum distilled to yield a residue of yellow crystals with m. p. 65-67°. Yield 23 g (95%).

Ethyl ester of benzylphenylacetic acid. A charge of 45 g (about 0.19 mole) of o-benzyl-ω-diazoacetophenone and 600 ml of anhydrous alcohol was placed in a three-necked flask fitted with a stirrer and reflux condenser. After solution had been obtained the whole was heated to 50-60° and then silver oxide, prepared by dissolving 11 g of $AgNO_3$ in 90 ml of water and then adding a solution of 2.6 g of NaOH in 25 ml of water, was added in portions. Too high an alkalinity of the Ag_2O solution is to be avoided. The silver oxide was washed with distilled water until neutral and then it was washed several times with anhydrous alcohol. The silver oxide was added as a suspension in alcohol. Nitrogen evolution began as soon as the first portion was added. After all of the silver oxide had been added, the mixture was heated gradually to the boil and then refluxed for 1 hour. The solution was cooled and the precipitate was filtered. The alcohol was distilled off and the ester was vacuum distilled, collecting the fraction with b. p. 140-158° (0.3 mm). We obtained 32 g of the ester as a slightly yellow viscous liquid.

Found %: C 80.0, 80.2; H 7.3, 7.4. $C_{17}H_{18}O_2$. Calculated %: C 80.3; H 7.1.

o-Benzylphenylacetic acid. A mixture of 32 g (0.12 mole) of ethyl o-benzylphenylacetate and an alcoholic solution of sodium hydroxide (30 g of NaOH, 30 ml of water, 75 ml of alcohol) was heated in a flask under reflux for 12 hours. The solution was then diluted with a large volume of water and acidified with dilute HCl (1 :1). The precipitate was filtered and then recrystallized from dilute acetic acid (1 g of precipitate per 3-4 ml of 60% CH_3COOH). We obtained 22.5 g of white needles with m. p. 89-91°. Yield 50%.

Dibenzo-6-suberone. o-Benzylphenylacetyl chloride was prepared in the same manner as o-benzylbenzoyl chloride.

For the synthesis we reacted 13.3 g (0.05 mole) of o-benzylphenylacetic acid with 6 ml of thionyl chloride in 25 ml of ether. After distilling off the solvent we obtained 14 g of the crude acid chloride with m. p. 40-42°.

A mixture of 20 g (0.15 mole) of anhydrous $AlCl_3$ and 500 ml of dry carbon disulfide was placed in a three-necked flask fitted with a stirrer, dropping funnel,and reflux condenser. A solution of 14 g of the acid chloride

* Correction for the exposed portion of the thermometer was not made in determining the boiling and melting points.

in 100 ml of carbon disulfide was added to the mixture. The reaction mixture was allowed to stand overnight. The carbon disulfide was distilled off and the residue was decomposed with ice. The ketone was extracted with ether, and the extract was washed with water, 10% caustic solution, again with water, and then it was dried over fused Na_2SO_4, followed by removal of the ether by distillation. The residue was vacuum distilled, collecting the fraction with b. p. 135-137° (0.3 mm). We obtained about 6 g of a slightly yellow oil, which crystallized. Recrystallization from methyl alcohol (3 ml per g of ketone) gave 4.6 g of white crystals with m. p. 70-72°. Yield 45%.

Dibenzosuberan-6,7-dione (I). A mixture of 9.5 g (0.045 mole) of dibenzo-6-suberone and 15 ml of glacial acetic acid was charged into a three-necked flask fitted with a stirrer, reflux condenser, and dropping funnel. A solution of 5.55 g (0.05 mole) of selenium dioxide in 50 ml of acetic acid and 3.5 ml of water was added to the boiling solution in 1.5 hours. The mixture was refluxed for 8 hours, allowed to stand overnight, and the selenium was removed by filtration. The filtrate was concentrated to a volume of about 10 ml and then cooled. We obtained 3.5 g of yellow crystals with m. p. 162-164°, which turn red when exposed to the light. Here the melting point does not change. Yield 36%.

Found %: C 80.9, 81.0; H 4.5, 4.7. $C_{15}H_{10}O_2$. Calculated %: C 81.1; H 4.5.

The quinoxaline was obtained by refluxing 0.2 g of the diketone with 0.11 g of o-phenylenediamine in acetic acid for 1 hour. The solution on cooling deposited pale-yellow needles with m. p. 229-231° (from acetic acid).

Monohydrazone (II). The diketone (2.2 g; 0.01 mole) was dissolved in 25 ml of either propyl alcohol or acetic acid. A solution of 2.0 g (0.04 mole) of hydrazine hydrate in 10 ml of propanol was added slowly to the cooled solution. The mixture warmed up and a small amount of nitrogen was evolved. The mixture was then filtered and allowed to stand overnight. After this the solvent was distilled off under a slight vacuum and yellow crystals were obtained when the residue was cooled in ice. We obtained 1.5 g of the monohydrazone with m. p. 131-132° (decomp.) (from either alcohol or benzene). Yield 65%.

Found %: C 76.13, 76.02; H 5.40, 5.29; N 11.64, 11.67. $C_{15}H_{12}ON_2$. Calculated %: C 76.27; H 5.08; N 11.86.

Hydrolysis of the monohydrazone. A mixture of 0.25 g (0.001 mole) of dibenzosuberan-6,7-dione monohydrazone, 2.5 ml of formalin and 1 ml of hydrochloric acid (1 :1) was heated under reflux for 2 hours. Then 10 ml of water was added and the obtained oil was separated. The oil was dissolved in a small amount of alcohol. The obtained crystals were filtered and then recrystallized from alcohol. We obtained 0.1 g of yellow needles with m. p. 160-162°. The substance failed to depress the melting point when mixed with the authentic diketone.

Reaction of hydrazine with dibenzosuberan-6,7-dione monohydrazone. A mixture of 0.6 g of the monohydrazone in 6 ml of propanol or acetic acid and 0.5 g of hydrazine hydrate was heated under reflux for 2 hours. The hot solution was filtered to give about 20 mg of a white deposit, which melted with decomposition around 280°. The deposit was insoluble in the common organic solvents and was not investigated further.

The alcohol solution was vacuum distilled and the residue was placed in a desiccator. After several days white needles deposited from the tarry residue. We obtained 0.1 g of product with m. p. 202-204° (from alcohol).

Found %: C 77.67; H 7.20; N 11.73, 11.50.

The same substances were obtained when the diketone was heated with either hydrazine hydrate or anhydrous hydrazine and when the monohydrazone was heated with anhydrous hydrazine.

Reaction of diazomethane with dibenzosuberan-6,7-dione monohydrazone. To 0.22 g (0.001 mole) of the monohydrazone in 10 ml of alcohol was added 5 ml of an ether solution containing 0.17 g (0.02 mole) of diazomethane. Gas evolution was not observed. The solution was allowed to stand overnight at room temperature, after which the ether was distilled off and from the residue we obtained 0.1 g of yellow crystals with m. p. 128-130°, which failed to depress the melting point when mixed with the authentic monohydrazone.

Reaction of dimethylhydrazine with dibenzosuberan-6,7-dione. A solution of 1.0 g of pure dimethylhydrazine in 5 ml of alcohol was added to a solution of 0.9 g of diketone (I) in 10 ml of alcohol. The solution warmed up, and on cooling deposited 0.3 g of crystals. The solvent was vacuum distilled to give an additional 0.2 g of crystals.

The substance is soluble only in pyridine, so it was dissolved in pyridine and precipitated with alcohol. We obtained 0.1 g of pale-yellow crystals with m. p. 247-248° (decomp.).

Found %: C 79.53, 79.51; H 4.81, 5.06.

Dumas analysis indicated that nitrogen was absent.

Dihydropyrazine (IV). A mixture of 0.45 g (0.002 mole) of the diketone, 0.20 g (0.0025 mole) of ethylenediamine and 5 ml of alcohol was heated under reflux. The solution was treated with animal charcoal, filtered, and the filtrate poured into water. The precipitate was filtered and recrystallized. We obtained 0.25 g of yellow crystals with m. p. 130-133° (from alcohol).

Found %: N 11.60, 11.55. $C_{17}H_{14}N_2$. Calculated %: N 11.38.

Reaction of hydrazine with dihydropyrazine (IV). A mixture of 0.2 g of the pyrazine, 0.2 g of hydrazine hydrate, and 2 ml of alcohol was heated under reflux for 24 hours. The solution was poured into water and the precipitate was filtered. After recrystallization we obtained 0.1 g of yellow crystals with m. p. 128-130° (from alcohol), which failed to depress the melting point when mixed with authentic dihydropyrazine (IV).

SUMMARY

1. Conditions were worked out for the synthesis of dibenzosuberan-6,7-dione.

2. The monohydrazone and the dihydropyrazine of dibenzosuberan-6,7-dione were obtained for the first time. The structure of the monohydrazone was established and it was proposed to have the syn-configuration.

3. It was shown that dimethylhydrazine does not give a derivative with dibenzosuberan-6,7-dione, but instead causes the condensation of the latter.

4. It was shown that dibenzosuberan-6,7-dione does not form the dihydrazone, which is explained by the presence of hydrogen bonding with conjugation (chelate ring).

LITERATURE CITED

[1] N. A. Domnin and N. S. Glebovskaya, Zhur. Obshchei Khim. 27, 656, 665 (1957).*

[2] A. T. Blomquist et al., J. Am. Chem. Soc. 73, 5510 (1951); 74, 3636, 3643 (1952); 75, 2153 (1953).

[3] V. Prelog et al., Helv. Chim. Acta 35, 1598 (1952); 36, 471 (1953); 38, 1776, 1786 (1955).

[4] N. A. Domnin, Zhur. Obshchei Khim. 6, 727 (1936).

[5] N. A. Domnin, Zhur. Obshchei Khim. 8, 851 (1938).

[6] A. P. Terent'ev et al., Nomenclature of Organic Compounds [In Russian] (Izd. AN SSSR, 1955), p. 189.

[7] J. Rigaudy and L. Nedelec, Compt. rend. 236, 1287 (1953).

[8] Han-Ching Yuan and Kou-Ching Hua, J. Chinese Chem. Soc. 7, 76 (1940).

[9] J. van Alphen, Rec. trav. chim. 54, 443 (1935).

[10] L. Gattermann and H. Wieland, The Practice of Organic Chemistry [Russian translation], (1948), p. 389.

[11] E. de B. Barnett et al., J. Chem. Soc. 1927, 504.

[12] Organic Syntheses [Russian translation], Coll: Vol. II, (1949), p. 147.

* Original Russian pagination. See C. B. translation.

REACTION OF MERCURIC ACETATE WITH CYCLOHEXYL 1,1-DIACETYLDIHYDROPEROXIDE AND BENZOYL PEROXIDE

Yu. A. Ol'dekop and N. A. Maier

Institute of Chemistry, Academy of Sciences, Belorus. SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 275-282, January, 1960

Original article submitted December 17, 1958

The chain reactions of mercuric acetate with cyclohexyl 1,1-diacetyldihydroperoxide (I) and benzoyl peroxide (II) were described by us earlier [1]. In this paper we studied the effect of temperature, the medium, and the initiator on the course of the chain reaction, and we also compared the ability of the methyl and phenyl radicals to initiate the chain radical decomposition of mercuric acetate. As convenient and relatively safe generators of the free methyl and phenyl radicals we used peroxides (I) and (II).

Reaction of mercuric acetate with the two peroxides was investigated in acetic acid at 80° ± 0.5° and 97-98°, in benzene at 80°, and in benzene containing acetic acid, also at 80°. In all of the experiments we used 0.03 mole of mercuric acetate and 100 ml of solvent. The amount of initiator was varied. The composition of the evolved gases was investigated. The gases were found to contain CO_2, CH_4, and C_2H_6.

The methylmercury salts were obtained in 95-98% yield when peroxide (I) was used to initiate the chain reaction. To obtain yields of this order in acetic acid at 80° required using 0.01 mole of peroxide (I) (Expts. 3 and 4). The yield dropped to 30-36% (Expts. 1 and 2) when only 0.005 mole of peroxide (I) was used under these conditions. In acetic acid at 97-98° the use of 0.005 mole of peroxide (I) gave CH_3HgX in 94.3% yield (Expt. 5), while with 0.01 mole of peroxide (I) the yield was practically quantitative (Expt. 6).

When the experiment was run in benzene even 0.01 mole of peroxide (I) gave only a 75% yield of CH_3HgX (Expt. 9). The addition of even 1.0 ml of acetic acid to the benzene raised the yield to 86.5%, while with 10 ml of acetic acid the yield of methylmercury compounds was practically quantitative (Expts. 10-12).

The yield of the other reaction products is also strongly dependent on the experimental conditions. In acetic acid at 80°, using 0.005 mole of peroxide (I), the amount of starting mercury salt recovered unchanged from the reaction was 57-60%. In agreement with this, the yield of CO_2 was 0.0071-0.0074 mole, of methane 0.0004 mole, and of mercurous acetate 3.21%, based on mercury salt taken (Expts. 1 and 2). With 0.01 mole of peroxide (I) the reaction already went to completion: the starting salt was absent in the reaction products. The yield of CO_2 increased nearly 4 times, that of methane increased 11-12 times (Expts. 3 and 4), while the yield of mercurous salt decreased to 1.16-1.29%. At 97-98°, the starting salt was absent in the reaction products even at 0.005 mole of peroxide (I), while with 0.01 mole the mercurous salt was also absent from the reaction products. Increasing the amount of peroxide (I) under these conditions also affected the yield of gaseous products, but not as strongly as at 80°. In benzene the unreacted mercury salt (14.6%) was present in the reaction products even at 0.01 mole of peroxide (I) (Expt. 9); the yield of mercurous acetate was 7.7%. The addition of 1.0 ml of acetic acid to the benzene reduced the yields of mercurous and mercuric acetates approximately to half, while both acetates were absent in the reaction products when 10 ml of CH_3COOH was added to the benzene. The addition of acetic acid was practically without effect on the yield of gaseous reaction products. It is interesting that the yield of ethane (Expts. 1-12) was independent of the amount of peroxide (I), but did depend on the

TABLE 1

Reaction of 0.03 Mole of Mercuric Acetate with Cyclohexyl 1,1-Diacetyldihydroperoxide (Peroxide I)

Expt. No.	Taken for reaction			Reaction temp.	Obtained after reaction						Reaction rate, $\frac{\Delta V_0}{\Delta \tau}$ (ml/min)	
	peroxide (I) (in moles)	acetic acid (in ml)	benzene (in ml)		CH_3HgX, yield based on Hg (%)	$Hg(OCOCH_3)_2$ (in % of amt. taken)	$Hg_2(OCOCH_3)_2$ (in % of amt. taken)	CO_2 (in moles)	CH_4 (in moles)	C_2H_6 (in moles)	for total gas	for alkanes
1	0.005	100	—	80°	36.0	57.3	3.21	0.0074	0.0004	0.00013	1.85	—
2	0.005	100	—	80	30.2	60.5	3.21	0.0071	0.0004	0.00012	—	—
3	0.01	100	—	80	95.4	0	1.16	0.027	0.0049	0.00014	11.0	—
4	0.01	100	—	80	94.3	0	1.29	0.026	0.0045	0.00014	—	—
5	0.005	100	—	97—98	94.3	0	1.93	0.0258	0.0031	0.0009	—	21.0
6	0.01	100	—	97—98	98.3	0	0	0.0404	0.0078	0.0010	—	43.0
7	0.01	—	100	80				0.0330	0.0022	0.00024	7.0	—
8	0.01	—	100	80				0.0374	0.0020	0.00025	—	~7
9	0.01	—	100	80	75.0	14.6	7.7				—	—
10	0.01	1.0	100	80	86.5	7.91	3.85	0.0357	0.0019	0.00018	—	—
11	0.01	10.0	100	80	93.3	0	0	0.0342	0.0017	0.00024	11.55	—
12	0.01	10.0	100	80	96.5	0	0	0.0377	0.0021	0.00025	—	~7

medium and the temperature. We did not investigate the transformations of the cyclohexyl radical of peroxide (I); here only an oil was isolated, which gave a positive test for the double bond with bromine water and with alkaline $KMnO_4$ solution.

To study the ability of phenyl radicals to cause chain decarboxylation of the salt we investigated the reaction of mercury acetate with benzoyl peroxide (II). The highest yield (95.5%) of methylmercury compounds was obtained in acetic acid at 97-98° and using 0.005 mole of peroxide (II). When the amount of peroxide (II) was increased under these conditions the yield of methylmercury compounds decreased, with a simultaneous increase in the yield of phenylmercury compounds (Expts. 15-17).

At 80° in acetic acid the yield of CH_3HgX was practically the same using either 0.005 or 0.01 mole of peroxide (II), and was 82.0-83.8% (Expts. 13 and 14). In benzene with 0.005 mole of peroxide (II) the yield was 40.3%. The addition of 10 ml of CH_3COOH to the benzene raised the yield to 64.7%. With 0.01 mole of peroxide (II) in benzene the yield of methylmercury compounds was 70% (Expt. 20).

Phenylmercury compounds were found in the reaction products in all of the experiments using peroxide (II). Their yield depends both on the amount of peroxide (II) and the experimental conditions. With equal amounts of the peroxide, the yield of phenylmercury compounds in acetic acid at 97-98° is higher than at 80° and in benzene it is higher than in acetic acid. With a large excess of peroxide (II) when compared to the mercury acetate (Expt. 17) the yield of phenylmercury compounds was 60%, based on the mercury salt. However, a substantial amount (39.1%) of methylmercury compounds was also formed in this experiment; this indicates that the phenyl radical, formed from peroxide (II), and the methyl radical, arising in the decomposition of the mercury acetate molecule, possess an approximately equal ability to continue the chain reaction. The original salt was absent in the reaction products in all of the experiments using peroxide (II) in acetic acid. With 0.005 mole of peroxide (II)

TABLE 2

Reaction of 0.03 Mole of Mercuric Acetate with Benzoyl Peroxide (Peroxide II)

Expt. No.	Taken for reaction: peroxide (II) (in moles)*	Taken for reaction: acetic acid (in ml)	Taken for reaction: benzene (in ml)	Reaction temp.	Obtained after reaction: CH_3HgX, yield based on Hg (%)	C_6H_5HgX, yield based on Hg (%)	$Hg(OCOCH_3)_2$ (in % of amt taken)	$Hg_2(OCOCH_3)_2$ yield based on Hg (%)	$C_6H_5-C_6H_5$ (in g)	C_6H_5COOH (in g)	CO_2 (in moles)	CH_4 (in moles)	C_2H_6 (in moles)	Total rate of gas evolution, $\frac{\Delta V}{\Delta \tau}$ (ml/min)
13	0.005	100	—	80°	82.0	2.24	0	14.15	0.02	0.01	0.0213	0.0019	0.00047	5.24
14	0.01	100	—	80	83.8	5.86	0	6.3	0.06	0.09	0.0295	0.0036	0.00019	11.4
15	0.005	100	—	97—98	95.5	3.09	0	0.65	0.02	0.02	0.0302	0.0038	0.00015	42.5
16	0.01	100	—	97—98	91.2	6.6	0	0	0.03	0.05	0.0368	0.0057	0.00016	63.4
17	0.035	100	—	97—98	39.1	60.15	0	0	0.25	0.20	0.067	0.0154	0.00064	—
18	0.005	0	100	80	40.3	7.03	34.4	15.4	0.15	0.03	0.0194	0.0011	0.00007	—
19	0.005	10	100	80	64.7	9.15	0	25.7	0.14	0.03	0.0225	0.0007	0.00015	—
20	0.01	0	100	80	70.0	11.7	0	17.33	0.23	0.30	0.0396	0.0029	0.00008	—

* Taken as 100%.

in benzene the amount of original salt remaining unchanged was 34.4% (Expt. 18); however, the addition of 10 ml of CH_3COOH to the benzene or using 0.01 mole of peroxide (II) caused the reaction to go to completion, and mercuric acetate was absent in the reaction products (Expts. 19 and 20). The yield of mercurous acetate in acetic acid decreased with increase in the amount of peroxide (II) and with increase in the temperature (Expts. 13-16). At the same time the yield of CO_2 increased from 0.0213 to 0.0368, while the yield of methane increased from 0.0019 to 0.0057 mole. The yield of mercurous acetate in benzene was substantially higher than in acetic acid.

In addition to the enumerated reaction products, we isolated biphenyl and benzoic acid, while in acetic acid medium it was shown that benzene is formed. These products are customary in the decomposition of benzoyl peroxide. The yield of biphenyl was higher in benzene than in acetic acid, due to reaction of the phenyl radical with benzene. When Expts. 9-12 and 18-19 are compared, it can be seen that the addition of small amounts of acetic acid to the benzene favors a more complete progress of the chain reaction and increases the yield of organometallic compounds. This phenomenon can probably be explained by the fact that the acetoxy radical $CH_3COO^\bullet$, taking part in the reaction, reacts with the acetic acid, resulting in the estafette** regeneration of the acetoxy radical [2]. This increases the rate of transfer of the $CH_3COO^\bullet$ radical into the reaction zone and, as a result, favors progress of the chain decomposition of the mercury acetate.

The curves for the evolution of gas during the course of reaction under different conditions are shown in Figs. 1 and 2. The general shape of the curves, with the exception of curves 18-20 in Fig. 2, is quite similar: all of them show a distinct linear portion, where the rate of gas evolution is constant. For these sections, we calculated the value of $\frac{\Delta v_0}{\Delta \tau}$ in milliliters per minute, characterizing the rate of gas evolution in the given experiment. In the case of curve 1* (Fig. 1), the linear portion is small, and $\frac{\Delta v_0}{\Delta \tau}$ is equal to a total of only 1.85 ml/min; the amount of evolved gas is also small. This corresponds to incomplete reaction in Expt. 1 (57.3% of the

* The numbering of the curves corresponds to the numbering of the experiments; the curves of the duplicate experiments (Nos. 2, 4, 9, etc.) are not given.

** Relay.

starting salt failed to react). Increasing the amount of peroxide (I) under these conditions (acetic acid, 80°) to 0.01 mole leads to increasing the value of $\frac{\Delta v_0}{\Delta \tau}$ to 11.0 ml/min; in this experiment the reaction goes to completion (Curve 3). The total amount of gas evolved when mercury acetate is reacted with peroxide (I) in acetic acid at 97-98° was studied by us earlier [1]. In the present paper, we investigated the evolution of saturated hydrocarbons under these conditions (Fig. 1). Linear sections can be seen on the obtained curves 5 and 6, indicating that the formation of hydrocarbons occurs not only as the result of the decomposition of peroxide

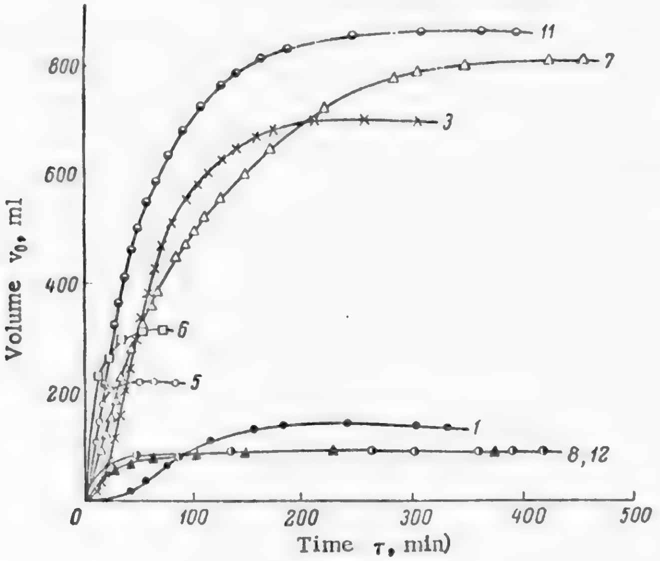


Fig. 1. Reaction of mercury acetate with peroxide (I): a) total amount of gas evolved in acetic acid at 80° (Curves 1 and 3); b) amount of saturated hydrocarbons evolved in acetic acid at 97-98° (Curves 5 and 6); c) total amount of gas (Curves 7 and 11) and hydrocarbons evolved (Curves 8 and 12) in benzene (Curves 7 and 8) and in benzene containing acetic acid (Curves 11 and 12).

(I), but also as the result of the chain reaction of the decarboxylation of mercury acetate. This conclusion is supported by the formation of methane and ethane in the experiments with benzoyl peroxide (II), which does not give $CH_3\cdot$ radicals in its decomposition (see Table 2). Figure 1 shows the effect of adding acetic acid on the total amount of gas evolved (Curves 7 and 11) and on the liberation of hydrocarbons (Curves 8 and 12) when mercury acetate is reacted with peroxide (I) in benzene. The values of $\frac{\Delta v_0}{\Delta \tau}$ for these curves are given in Table 1. From Fig. 2, it can be seen that when mercury acetate is reacted with peroxide (II) in acetic acid at 80° the evolution of gas does not start immediately, but only after the lapse of 1 to 1.5 hours (Curves 13 and 14). The shape of the curves permits assuming that under these conditions the reaction goes autocatalytically. Such an induction period is absent at 97-98°, and here reaction begins immediately after adding the initiator. The reaction rate is considerably higher at 97-98° than at 80° (compare Curves 13 and 15, and 14 and 16). When mercury acetate is reacted with peroxide (II) in benzene the linear portion on the curves for gas evolution is absent (Fig. 2); for this reason the value of $\frac{\Delta v_0}{\Delta \tau}$ was not calculated for these curves. A comparison of Curves 18 and 19 reveals that under these conditions the addition of acetic acid promotes more vigorous progress of the reaction. From a comparison of Curves 1 and 3, 5 and 6 (Fig. 1), 13 and 14, 15 and 16, and 18 and 20 (Fig. 2), it is obvious that increasing the amount of initiator leads to increasing the reaction rate and to an

increase in the volume of gas evolved. In some of the experiments, this also leads to more complete reaction and to an increase in the yield of organometallic compounds (see Tables 1 and 2).

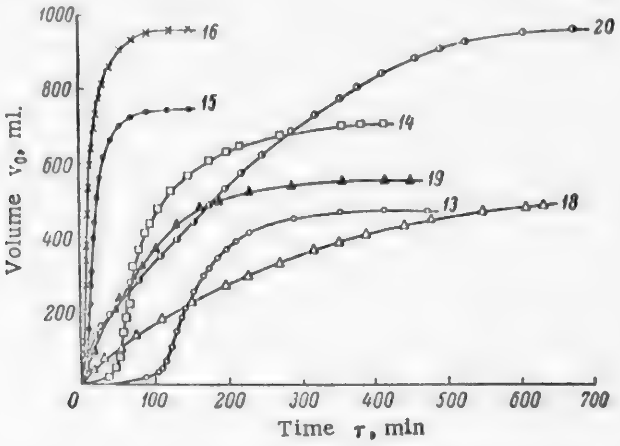


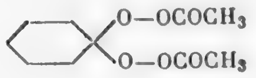
Fig. 2. Reaction of mercury acetate with peroxide (II): a) total amount of gas evolved in acetic acid at 80° (Curves 13 and 14); b) total amount of gas evolved in acetic acid at 97-98° (Curves 15 and 16); c) total amount of gas evolved in benzene (Curves 18 and 20) and in benzene containing acetic acid (Curve 19).

EXPERIMENTAL

In our work we used c. p. acetic acid without further purification. The analytically pure benzene was purified from thiophene and distilled over sodium. The "pure" mercuric acetate was washed with benzene and then dried in the dark.

Found %: Hg 62.82, 63.05. $C_4H_6O_4Hg$. Calculated %: Hg 62.96.

Cyclohexyl 1,1-diacetyldihydroperoxide (peroxide I) was prepared by the method of [3] and had m. p. 73°. According to [4], the formula assigned to this compound is



Benzoyl peroxide was prepared and purified by the method of [5]. Iodometric titration by the method of [6] indicated that the peroxide had a purity of 98-98.5%. The reaction was run in the apparatus described by us earlier. The accumulation of gases in the burets was measured at regular time intervals. To study the rate with which the saturated hydrocarbons are liberated, we used a KOH absorption tube, and when determining the total amount of gas evolved we disconnected the KOH absorption tube. Heating and stirring of the reaction mass was continued until the evolution of gas ceased. At the end of experiment, the system was blown with air that had been freed of CO_2 and moisture, the same as was described earlier [1]. The collected gas was analyzed in the same manner as described in [1]. The melting points of the compounds isolated from the reaction products were verified by taking the mixed melting points with the pure materials.

1. Reaction of mercury acetate with cyclohexyl 1,1-diacetyldihydroperoxide (I) in acetic acid at 80° ± ± 0.5° and 97-98° (Table 1, Fig. 1, Curves 1 and 3, and 5 and 6). A solution of peroxide (I) in 25 ml of acetic acid was added rapidly to a hot mixture of 9.6 g (0.03 mole) of mercuric acetate and 75 ml of acetic acid. The reaction time at 80° was 5 hours, and at 97-98° it was 2 hours. Then the reaction mass was cooled and the

precipitate of mercurous acetate was separated (tests with KI, KCl, NH_4OH). The acetic acid was distilled from the filtrate. The unreacted mercuric acetate was separated from the methylmercury acetate by treatment of the residue with cold benzene, and then the methylmercury acetate was isolated from the benzene solution by extraction with water; treatment of the water extract with KI gave a precipitate of CH_3HgI, m. p. 143-144° (from alcohol or ether). The benzene solution from the water wash was evaporated in a dish; the residue was an oil (approximately 0.1 g), which gave a positive test for the double bond with bromine water and with $KMnO_4$ solution. The oil was not investigated further.

2. Reaction of mercury acetate with peroxide (I) in benzene and in mixtures of benzene with acetic acid at 80° (Table 1, Fig. 1, Curves 7 and 8, and 11 and 12). A solution of 2.32 g (0.01 mole) of peroxide (I) in 25 ml of benzene was added rapidly to a boiling mixture of 9.6 g (0.03 mole) of mercury acetate and 75 ml of benzene (acetic acid was added to the mixture in some of the experiments). The reaction time was 7.5-8 hours in the experiments without the addition of acetic acid and 6.5-7 hours in the experiments with the addition of acetic acid. A mixture of mercuric and mercurous acetates separated from the reaction mass on cooling. This precipitate was filtered and the methylmercury acetate was isolated from the benzene solution by extraction with water; treatment of the water extract with KI gave CH_3HgI with m. p. 143-144° (from alcohol or ether). The benzene was distilled from the water-washed benzene solution to give an oil (1-1.5 g) as residue, which gave a positive test for the double bond with bromine water and with $KMnO_4$ solution. The oil was not investigated further.

3. Reaction of mercury acetate with benzoyl peroxide (II) in acetic acid at 80° ± 0.5° and 97-98° (Table 2, Fig. 2, Curves 13, 14, 15, and 16). A small cartridge was used to add the weighed amount of peroxide (II) to the hot mixture of 9.6 g (0.03 mole) of mercury acetate and 100 ml of acetic acid. The reaction was run for 7-8 hours at 80° and for 2-2.5 hours at 97-98°. At 80° the evolution of gas began only after approximately 1.5 hours from the time of adding the peroxide. The reaction mass was cooled and the precipitate of mercurous acetate was separated. The acetic acid was removed by distillation from the acetic acid solution. The residue was dissolved in benzene. The above-described method was used to isolate the methylmercury derivatives (obtained as the iodide, m. p. 143-144°) from the benzene solution. The benzene was distilled from the water-washed benzene solution. The residue was treated with KCl, and the mixture was steam distilled. Phenylmercury chloride, m. p. 253-254° (from acetone), was isolated from the still residue. The steam distillate was made alkaline and the biphenyl was filtered off; m. p. 68-69°. The aqueous filtrates from the steam distillate and the still residue were evaporated and then acidified to give benzoic acid; m. p. 120° (from water). In some of the experiments the filtrate from the reaction mass was distilled until about 20 ml of distillate had been collected. This distillate was diluted with water and the solution was extracted with CCl_4. The extract was nitrated. Removal of the CCl_4 gave a residue of m-dinitrobenzene with m. p. 89-90° (from alcohol). An acetone solution of the compound gave a violet color when treated with KOH. Unreacted mercuric acetate was absent in the reaction products.

4. Reaction of mercury acetate with peroxide (II) in benzene and in mixtures of benzene with acetic acid at 80° (Table 2, Fig. 2, Curves 18, 19, and 20). A solution of peroxide (II) in 25 ml of benzene was added rapidly to a boiling mixture of 9.6 g (0.03 mole) of mercury acetate and 75 ml of benzene (10 ml of CH_3COOH was added in some of the experiments). The reaction was run for 10.5-11 hours without the acetic acid and 7.5-8 hours when acetic acid was present. The reaction mass was cooled and the precipitate was separated. This precipitate was analyzed for the amount of mercurous and mercuric salts. From the benzene solution, using the above-described method, we isolated the methyl- and phenylmercury compounds, biphenyl, and benzoic acid.

SUMMARY

1. A study was made of the reaction of mercuric acetate with cyclohexyl 1,1-diacetyldihydroperoxide and benzoyl peroxide in acetic acid, benzene, and their mixtures.

2. It was shown that increasing the amount of initiator and raising the temperature, and also having acetic acid present in the reaction mixture, all favor reaction progress.

3. The composition of the evolved gas was investigated; it was shown that in all cases the gas was composed of carbon dioxide, methane, and ethane.

LITERATURE CITED

[1] Yu. A. Ol'dekop and N. A. Maier, Zhur. Obshchei Khim. 30, 299 (1960); *G. A. Razuvaev, Yu. A. Ol'dekop, and N. A. Maier, Doklady Akad. Nauk SSSR 98, 613 (1954); G. A. Razuvaev, Yu. A. Ol'dekop, and N. A. Maier, Zhur. Obshchei Khim. 25, 697 (1955).*

[2] N. N. Semenov, Some Problems in Chemical Kinetics and Reactivity [In Russian] (Moscow, 1954), p. 155.

[3] W. Cooper, J. Chem. Soc. 1951, 1340.

[4] G. A. Razuvaev, L. V. Stupen, and K. S. Minsker, Zhur. Obshchei Khim. 26, 473 (1956);*Yu. A. Ol'dekop and I. I. Chizhevskaya, Trudy Inst. Khim. Akad. Nauk Belorus. SSR 7, 68 (1959).

[5] R. Criegee, Methoden der Organischen Chemie (Houben-Weyl)(1952) 4th Ed, Vol. 8, p. 39.

[6] C. D. Wagner, R. H. Smith, and E. D. Peters, Ind. Eng. Chem., Anal. Ed. 19, 976 (1947).

* Original Russian pagination. See C. B. translation.

SOME DIETHYLENIMINOTRIAZINE DERIVATIVES OF α-AMINO ACIDS

A. Ya. Berlin and V. K. Antonov

Institute of Experimental Pathology and Cancer Therapy,

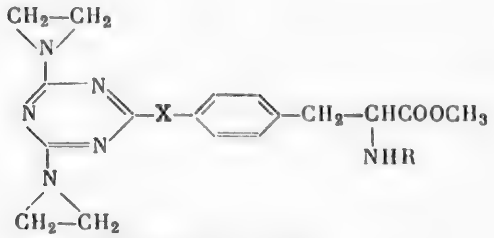
Academy Medical Sciences USSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 282-286, January, 1960

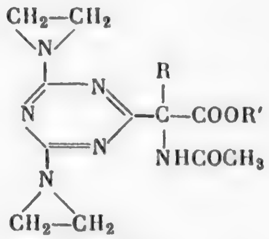
Original article submitted December 17, 1958

As the investigations of a number of authors [1] have shown, the introduction of cytotoxic groupings into amino acids can exert a favorable effect on the antitumor properties of the resulting products. Such a product that has found successful use is sarcolysin {p-[bis(2-chloroethyl)amino] phenylalanine}. On the other hand, replacing the hydrogen atom in the phenolic hydroxyl of tyrosine by the p-bis(2-chloroethyl)aminophenyl grouping leads to a completely inactive product [2].

In order to compare antitumor properties, it seemed of interest to us to synthesize some α-amino acids containing as substituents diethyleniminotriazine compounds of the type of (I), (II), and (III), all being analogs of 2,4,6-triethylenimino-s-triazine (TET), a product used in the treatment of leucoses, but having a high toxicity.



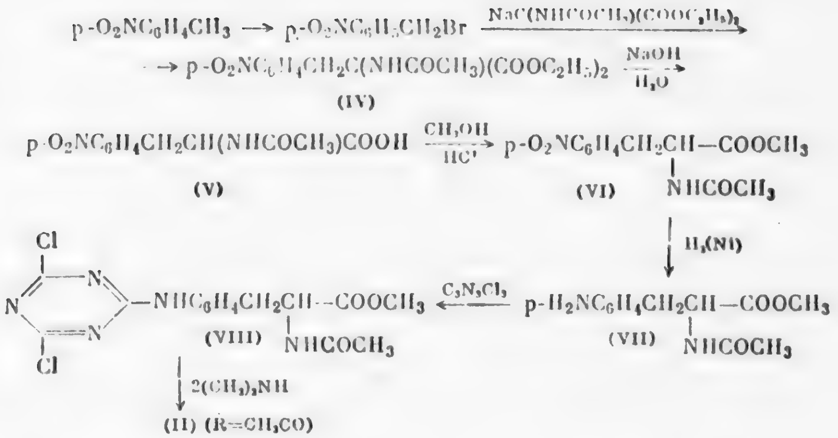
(I) X = O; (II) X = NH



(III)

The condensation of the sodium salt of the methyl ester of N-formyl-L-tyrosine with 2-chloro-4,6-diethylenimino-s-triazine in anhydrous medium gave the methyl ester of α-N-formyl-O-(4,6-diethylenimino-s-triazin-2-yl)-L-tyrosine (I, R = CHO) in 40% yield. In a similar manner the methyl ester of N-acetyl-L-tyrosine was converted to the corresponding acetyl derivative (I, R = CH_3CO) in 26.5% yield. Varying the acyl group seemed of interest in view of the fact that the N-formyl and N-acetyl derivatives of sarcolysin are quite different in their activity [3].

Synthesis of the methyl ester of α-N-acetyl-p-(4,6-diethylenimino-s-triazin-2-yl)amino-DL-phenylalanine (II, R = CH_3CO) was accomplished by the scheme:



Saponification of the diethyl ester of p-nitrobenzylacetamidomalonic acid (IV) with aqueous caustic enabled us to cleave both ester groups at the same time, leaving the acetyl grouping untouched. The thus obtained N-acetyl-p-nitrophenylalanine (V) was esterified with methyl alcohol in the presence of dry hydrogen chloride, and the obtained ester (VI) was hydrogenated over skeletal nickel. Attempts to condense amino ester (VII) directly with 2-chloro-4,6-diethylenimino-s-triazine proved unsuccessful. Consequently (VII) was condensed with cyanuric chloride and the obtained dichlorotriazine derivative (VIII) by reaction with ethylenimine and triethylamine was converted to (II, R = CH_3CO). The yields in the different synthesis steps range from 40 to 60%.

The condensation of 2-chloro-4,6-diethylenimino-s-triazine with potassioacetamidomalonic ester gave the diethyl ester of N-acetamido-(4,6-diethylenimino-s-triazin-2-yl)malonic acid (III, R = $COOC_2H_5$, R' = C_2H_5), but we were unable to saponify and decarboxylate this compound to (III, R = R' = H).

The results of the biological testing* of compounds (I, R = CHO), (I, R = CH_3CO), (II, R = CH_3CO), and (III, R = $COOC_2H_5$, R' = C_2H_5) will be published separately.

EXPERIMENTAL

1. The methyl ester of L-tyrosine was obtained by the Fischer method [4], m. p. 132.5-134° (m. p. 135 to 136° [4]).

2. Methyl ester of N-formyl-L-tyrosine. A mixture of 57 ml of 85% HCOOH and 19 ml of $(CH_3CO)_2O$ was added to 5 g of methyl L-tyrosinate. The mixture was cooled to 30° and allowed to stand for 30 minutes. Then the excess HCOOH and $(CH_3CO)_2O$ were vacuum distilled at a bath temperature not above 65°. The residue was dissolved in 50 ml of ethyl acetate and the solution was washed once with a mixture of 5 ml of concentrated HCl and 20 ml of saturated NaCl solution, and 6 times (until neutral) with 15-ml portions of saturated NaCl solution. The solution was dried over Na_2SO_4, and the solvent was distilled off. Yield 3.3 g (57%). M. p. 141-141.5° (from ethyl acetate).

Found %: C 59.06; H 5.84. $C_{11}H_{13}O_4N$. Calculated %: C 59.18; H 5.86.

3. Methyl ester of α-N-formyl-O-(4,6-diethylenimino-s-triazin-2-yl)-L-tyrosine (I, R = CHO). A solution of 1.28 g of 2-chloro-4,6-diethylenimino-s-triazine in 60 ml of dry acetone was prepared by heating. At the same time 1.45 g of methyl N-formyl-L-tyrosinate was dissolved in 30 ml of dry acetone, and then a solution of 0.32 g of NaOH in 10 ml of anhydrous CH_3OH was added. The phenolate solution was added to the triazine solution in 10 minutes at 20-22°. The mixture was stirred for 30 minutes and then the deposited NaCl was filtered.

* Done by E. M. Shamaeva.

The filtrate was evaporated in vacuo to dryness, and the residual oil was triturated with 10 ml of ether. The crystalline product was suction filtered and dried in a desiccator. Weight 2 g. The ester was recrystallized twice from 11 ml of a mixture (2:1) of acetone and petroleum ether, using activated carbon. M. p. 131.5 to 132.2° (the capillary was placed in the apparatus at 120°), $[\alpha]^{25}D$ + 29.5° (with 1.5% CH_3OH). The compound is soluble in water, alcohol, acetone, and ethyl acetate, and difficultly soluble in ether, petroleum ether, and hexane.

Found %: C 56.23; H 5.37; N 21.83. $C_{18}H_{20}O_4N_6$. Calculated %: C 56.23; H 5.24; N 21.86.

4. The methyl ester of N-acetyl-L-tyrosine was obtained by the Jackson method [5], m. p. 134-135°.

5. Methyl ester of α-N-acetyl-O-(4,6-diethylenimino-s-triazin-2-yl)-L-tyrosine (I, R = CH_3CO). A solution of 2.66 g of 2-chloro-4,6-diethylenimino-s-triazine in 120 ml of dry acetone was prepared by heating. A solution of 3.2 g of methyl N-acetyltyrosinate in 60 ml of acetone and 0.6 g of NaOH in 20 ml of anhydrous CH_3OH were added to the solution at 5-7°. The mixture was stirred for 30 minutes at 5°. The obtained NaCl precipitate was filtered, and the filtrate was evaporated in vacuo. The residual oil was triturated for some time with ether, using strong cooling. The solidified product was heated with a mixture of 20 ml of ethyl acetate and 7 ml of hexane, using activated carbon, and then filtered. The filtrate was placed in the refrigerator and after long standing we obtained 1.4 g (26.5 %) of the ester as fine crystals, forming spherical clusters. M. p. 106.5 to 107.5°, $[\alpha]^{25}_D$+20.89° (with 1.3855% CH_3OH). Soluble in water, alcohol, and acetone, and difficultly soluble in ether.

Found %: C 56.83; H 5.90; N 21.06. $C_{19}H_{22}O_4N_6$. Calculated %: C 57.27; H 5.56; N 21.09.

6. The diethyl ester of p-nitrobenzylacetamidomalonic acid (IV) was obtained by the Burckhalter and Stephens method [6], m. p. 193° (from 95% alcohol).

7. N-Acetyl-p-nitrophenylalanine (V). A mixture of 11.3 g of diester (IV), 2.4 g of NaOH and 60 ml of water was refluxed for 3 hours until all of the diester had dissolved. The mixture was cooled, filtered, acidified to Congo, and extracted (3 times 70 ml) with ethyl acetate. The solution was dried over Na_2SO_4, shaken with carbon, filtered, and the solvent was vacuum distilled. The residue was stirred with ether and the solution filtered. Yield 5.0 g (62%). Needle crystals. M. p. 198-199° (from water or 10% alcohol).

Found %: C 51.95; H 4.97; N 11.11. $C_{11}H_{12}O_5N_2$. Calculated %: C 52.38; H 4.79; N 11.18.

8. Methyl ester of N-acetyl-p-nitrophenylalanine (VI). A stream of dry HCl was passed through a mixture of 6.1 g of N-acetyl-p-nitrophenylalanine and 80 ml of anhydrous CH_3OH for 2 hours. The mixture was allowed to stand for 1 hour, after which the alcohol was vacuum distilled. The residue was treated with 5% $NaHCO_3$ solution until neutral, and then it was extracted with 200 ml of ethyl acetate. The solution was washed with water, dried over Na_2SO_4, and the solvent was distilled off. Yield 4.0 g (40%). M. p. 112-113° (from a mixture of 1:10 hexane-benzene).

9. Methyl ester of α-N-acetyl-p-aminophenylalanine (VII). A solution of 4.0 g of nitro compound (VI) in 60 ml of anhydrous alcohol was hydrogenated over skeletal nickel at 45-50°. The theoretical amount of hydrogen was absorbed in 3 hours. The catalyst was filtered and the filtrate was evaporated. The residual oil was triturated with petroleum ether under cooling. Yield 2.0 g (57%). M. p. 124.5-125.5° (from 35 ml of a 10:1 mixture of benzene and alcohol).

Found %: C 61.16; H 6.89. $C_{12}H_{16}O_3N_2$. Calculated %: C 61.00; H 6.83.

10. Methyl ester of α-N-acetyl-p-(4,6-dichloro-s-triazin-2-yl)-amino-DL-phenylalanine (VIII). A solution of 1.82 g of cyanuric chloride in 15 ml of acetone was poured into 100 ml of water cooled to 5°. The obtained suspension was treated with a solution of 1.35 g of $NaHCO_3$ in 10 ml of water, and then a solution of 3.7 g of the methyl ester of α-N-acetyl-p-aminophenylalanine in 30 ml of acetone was added in drops at 0-5°. The mixture was stirred for 45 minutes, after which it was suction filtered, and the precipitate was dried in a vacuum desiccator over $CaCl_2$. Yield 3 g (50%). M. p. 229-229.5° (decomp.) (recrystallized twice from dioxane).

Found %: C 47.08; H 4.25; N 17.90; Cl 18.53. $C_{15}H_{15}N_5O_3Cl_2$. Calculated %: C 46.88; H 3.93; N 18.23; Cl 18.46.

11. Methyl ester of α-N-acetyl-p-(4,6-diethylenimino-s-triazin-2-yl)-amino-DL-phenylalanine (II, R = CH_3CO). A solution of 5 g of dichloro derivative (VIII) in 80 ml of dioxane was added in drops to a solution of 1.7 ml (1.4 g) of ethylenimine and 3.7 ml of triethylamine in 40 ml of dioxane at 30-35°. The mass was stirred at 35° for 2 hours and then it was allowed to stand overnight. The next day the mixture was filtered to remove the triethylamine hydrochloride, and the filtrate was evaporated in vacuo. The residual oil was dissolved in 20 ml of ethyl acetate, and the solution was filtered and poured into 80 ml of ether. The mixture was diluted with 200 ml of petroleum ether and allowed to stand in the refrigerator overnight. Then the solvent was decanted from the precipitate. The precipitate was stirred with petroleum ether and filtered, and then it was mixed with 15 ml of anhydrous alcohol, triturated, and filtered. Yield 2.1 g (40.5 %). M. p. 160-161° (from alcohol) (capillary placed in the apparatus at 155°).

Found %: C 56.95; H 5.88; N 24.92. $C_{19}H_{23}O_3N_7$. Calculated %: C 57.42; H 5.83; N 24.67.

The compound is difficultly soluble in water, cold alcohol, ether and benzene, and readily soluble in hot water, warm alcohol, and chloroform.

12. Diethyl ester of N-acetamido-(4,6-diethylenimino-s-triazin-2-yl)-malonic acid (III) (R = $COOC_2H_5$, R' = C_2H_5). A solution of 2.05 g of acetamidomalonic ester in 20 ml of warm benzene was added to a suspension of 0.35 g of metallic potassium in 10 ml of benzene. The mixture was stirred for 10 minutes and then 0.75 ml (50% excess) of anhydrous alcohol was added with stirring. After this the mixture was treated with a solution of 1.7 g of 2-chloro-4,6-diethylenimino-s-triazine in 50 ml of benzene. The mixture was heated for 3 hours at 60° and then allowed to stand overnight. After this the solution was filtered from KCl and the filtrate was evaporated to dryness, after which the residue was treated with 20 ml of alcohol, filtered, and the filtrate evaporated again. The residue was stirred with ether, filtered, and the filtrate allowed to stand in the refrigerator. The obtained ester was suction filtered. Yield 0.9 g (28%). M. p. 132-133° (from a 1:1 mixture of benzene and cyclohexane) (the product reddens at 125°). The compound is difficultly soluble in water, and readily soluble in benzene and alcohol.

Found %: C 50.98; H 5.88; N 21.83. $C_{16}H_{22}O_5N_6$. Calculated %: C 50.82; H 5.89; N 22.21.

Slightly soluble in water, very soluble in benzene, alcohol.

The alcohol and ether-insoluble precipitate (0.5 g) was starting 2-chloro-4,6-diethylenimino-s-triazine. When an attempt was made to saponify the obtained ester using alcoholic NaOH solution, we isolated a non-crystalline substance that failed to have a definite melting point, and which we were unable to purify.

SUMMARY

The methyl esters of α-N-formyl- and α-N-acetyl-O-(4,6-diethylenimino-s-triazin-2-yl)-L-tyrosine, the methyl ester of α-N-acetyl-p-(4,6-diethylenimino-s-triazin-2-yl) amino-DL-phenylalanine, and the diethyl ester of N-acetamido-(4,6-diethylenimino-s-triazin-2-yl) malonic acid were synthesized.

LITERATURE CITED

[1] L. F. Larionov, A. S. Khokhlov, et al., Byull. Éksptl. Biol. i Med. 39, 48 (1955); M. Ishidate, Y. Sakurai, and M. Izumi, J. Am. Pharm. Assoc. 44, 132 (1955); F. Bergel and J. A. Stock, J. Chem. Soc. 1954, 2409.

[2] F. Bergel and G. Lewis, J. Chem. Soc. 1957, 1816.

[3] N. A. Vodolazskaya, M. A. Novikova, E. N. Shkodinskaya, O. S. Vasina, A. Ya. Berlin, and L. F. Larionov, Byull. Éksptl. Biol. i Med. 41, 76 (1957).*

[4] E. Fischer, Lieb. Ann. 354, 4 (1907).

[5] E. Jackson, J. Am. Chem. Soc. 74, 837 (1952).

[6] J. Burckhalter and V. Stephens, J. Am. Chem. Soc. 73, 56 (1951).

* Original Russian pagination. See C. B. translation.

THE STRUCTURE AND TRANSFORMATIONS OF DIAZO COMPOUNDS

XII. SPECTRAL INVESTIGATIONS OF SOME AROMATIC DIAZO COMPOUNDS

B. A. Porai-Koshits and B. V. Passet

Lensovet Leningrad Technological Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 286-290, January, 1960

Original article submitted January 15, 1959

Only a few papers are devoted to the obtaining and study of the electronic absorption spectra of diazo compounds. It is known that in aliphatic diazo compounds the diazo group gives two characteristic absorption bands of different intensity [1]. The intense band lies at 250 mμ, while the low-intensity, longer wavelength band lies in the 350-400 mμ region. Even less is known about the electronic absorption spectra of aromatic diazo compounds, which are the subject of the present investigation. The studies made in this area by Hantzsch and Lifschitz [2], and also those of Dobbie and Tinkler [3], had as their goal only to establish a similarity or difference in the absorption spectra of the so-called "stable" and "labile" salts. The recent studies of Le Fevre [4], in which he used the electronic spectra to study the influence of light on diazo compounds, contains much incorrect data, which was shown by Lewis [5], and is also confirmed by our experiments. Undertaking a study of the structure of diazo compounds, some investigators have resorted to a study of the infrared spectra [6-16]. Meanwhile, electronic spectra are especially important when discussing the problems associated with the electronic structure of compounds.

Our study of the spectra of diazo compounds in acid medium revealed that the presence of two absorption bands of different intensity is characteristic for the diazo cation. Depending on the character of the substituent in the aromatic nucleus, the absorption band with the higher intensity lies at 260-280 mμ, while the less intense band lies at 300-350 mμ (Fig. 1).

The absorption curves of diazo compounds in strongly alkaline medium are sharply different from the absorption curves in acid medium. The diazo anions showed only one absorption band in the near ultraviolet with maximum absorption at 275-330 mμ, depending on the character of the substituent in the aromatic nucleus (Fig. 2).

Diazo compound	Absorption maxima (mμ) characteristic		Presence of isobestic points (mμ)
	for cation	for anion	
o-Methoxydiazobenzene	266, 355	223, 273	250, 274, 327
Diazobenzene	263, 300	273	245, 268
p-Sulfodiazobenzene	269, 310	281	245, 278
p-Nitrodiazobenzene	260, 312	330	238, 280
2,6-Dichlorodiazobenzene	277, 347	< 220	248

In the pH range 7-9 the absorption curves of water solutions of the diazo compounds are strongly dependent on the pH of the medium, at all times occupying an intermediate position between the absorption curves of the diazo cation (Fig. 1) and the diazo anion (Fig. 2). Especially important is the fact that the absorption curves of any diazo compound all intersect at one point, irrespective of the pH (Fig. 3).

The presence of isobestic points on the absorption curves of diazo compounds (see Table) indicates that, independent of the pH for all practical purposes there are no other forms of diazo compounds, besides diazo cation and diazo anion, present in the aqueous solutions when equilibrium is established, which supports the theory expressed by us earlier [17]. Zollinger and Wittwer [18, 19] also expressed the opinion that perceptible amounts of undissociated forms of diazo compounds are absent in aqueous solutions, but this opinion lacked sufficient experimental proof.

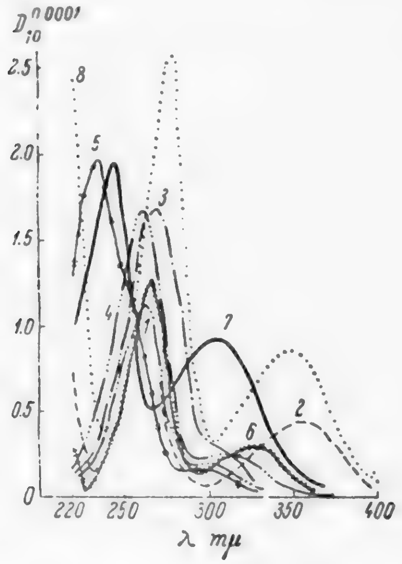


Fig. 1. Absorption curves of water solutions of diazo compounds in acid medium (pH 3-4). 1) Diazobenzene; 2) o-methoxydiazobenzene; 3) p-sulfodiazobenzene; 4) p-nitrodiazobenzene; 5) m-nitrodiazobenzene; 6) o-chlorodiazobenzene; 7) 2,4-dinitrochlorodiazobenzene; 8) 2,6-dichlorodiazobenzene.

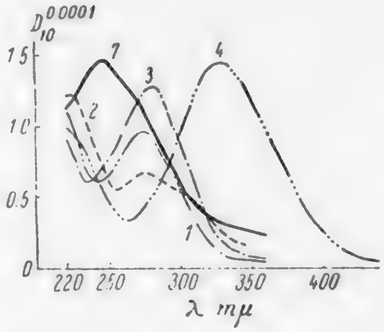


Fig. 2. Absorption curves of water solutions of diazo compounds in alkaline medium (at pH 11-12). See Fig. 1 for the numbering of the curves.

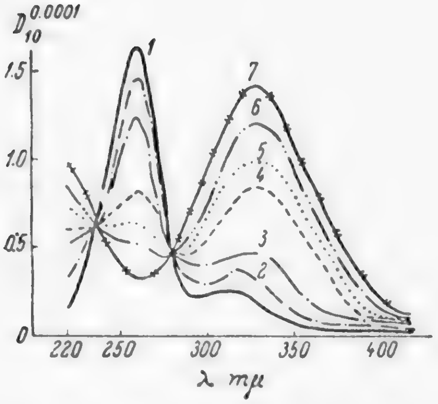


Fig. 3. Absorption curves of aqueous solutions of p-nitrodiazobenzene at different pH values. pH values: 1) ≤ 4.0; 2) 7.0; 3) 7.38; 4) 7.67; 5) 7.80; 6) 7.98; 7) ≥ 11.

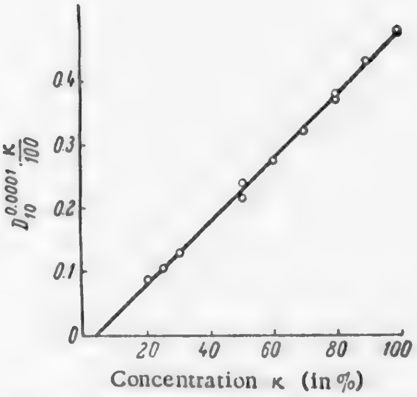


Fig. 4. Relation between the optical density of aqueous solution of p-nitrodiazobenzene at λ = 280 mμ and the concentration of diazo compound.

Simultaneously with us, it was independently shown by Lewis and Suhr [5] that isobestic points exist for the case of p-nitrodiazobenzene. However, the mentioned investigators did not extend their study to other diazo compounds and failed to derive any other conclusions from it except that their experiments support Zollinger's theories. Lewis and Suhr were also unable to study the established equilibrium, and consequently they were unable to calculate the equilibrium constant accurately.

Since the isobestic point lies at the intersection of the absorption curves of the diazo cation and the diazo anion, the optical density of the solution at a wavelength corresponding to the isobestic point should be proportional to the total amount of diazo compound in the solution. This permitted us to find the graphical relationship for determining the concentration of diazo compound in solution, which is shown in Fig. 4. Along the ordinate, we have plotted the optical density values of diazo solutions containing different amounts, determined analytically, of diazo compound, while along the abscissa we have plotted the corresponding concentration of diazo compound (in the given case,p-nitrodiazobenzene). The existence of such a relationship makes it possible to determine rapidly and accurately the concentration of diazo compound in solution, independent of whether it is found as diazo cation or as diazo anion.

Being convinced that dilute water solutions of diazo compounds obey the Lambert-Beer law at all pH values, we were able to utilize the method described in [20] for the analysis of diazo solutions, with a separate determination of the amounts of diazo cation and diazo anion, and thus obtain a more accurate value for the hydrolysis constant of the diazo cation, which, according to earlier determination by gravimetric analysis [17], was equal to $K = 10^{-15.2}$.

$$O_2NC_6H_4N_2^{\oplus} + H_2O \rightleftarrows O_2NC_6H_4N_2O^{\ominus} + 2H^{\oplus}$$

$$K = \frac{[O_2NC_6H_4N_2O^{\ominus}]\,[H^{\oplus}]^2}{[O_2NC_6H_4N_2^{\oplus}]} \tag{1}$$

This also helped us to determine those physicochemical constants of diazo compounds that function to characterize their acid-base properties. The values of these constants for p-nitrodiazobenzene proved to be equal to:

1) equilibrium (hydrolysis) constant, $K = 6.31 \cdot 10^{-16}$;

2) acidity constant of p-nitrophenylnitrosamine, $K_a = 2.51 \cdot 10^{-6}$;

3) first acidity constant of p-nitrophenyldiazo cation, $K_{a_I} = 2.51 \cdot 10^{-10}$;

4) first basicity constant of p-nitrophenyldiazo anion, $K_{b_I} = 1.58 \cdot 10^{-9}$;

5) second basicity constant of p-nitrophenyldiazo anion (basicity constant of p-nitrophenyldiazo hydroxide), $K_{b_{II}} = 1.58 \cdot 10^{-5}$.

Quantitative spectral investigation of water solutions of p-nitrodiazobenzene revealed:

1) when equilibrium is established the sum of the diazo cation and diazo anion concentrations is equal to the solution concentration of the diazo compound at all pH values of the solution;

2) when equilibrium (2)

$$ArN_2^{\oplus} + OH^{\ominus} \rightleftarrows ArN_2OH \xrightleftharpoons{OH^{\ominus}} ArN_2O^{\ominus} + H_2O \tag{2}$$

is not established, the sum of the concentrations of diazo cation and diazo anion at any moment is equal to the solution concentration of the diazo compound, which serves as evidence that the rate of the second step of the reaction is much faster than the rate of the first step;

3) when equilibrium (3)

$$ArN_2O^{\ominus} + H_3O^{\oplus} \rightleftarrows Ar{-}N_2OH \xrightleftharpoons{H_3O^{\oplus}} ArN_2^{\oplus} + 2H_2O \tag{3}$$

is not established, the sum of the concentrations of diazo cation and diazo anion is smaller than the solution concentration of the diazo compound, which serves as evidence that the rate of the second step of the reaction is slower than the rate of the first step.

The use of electronic absorption spectra to study the changes in the concentration of diazo cation and diazo anion during the initial period of reaction (2) revealed that in the pH range 7-9 this reaction does not obey the first-order equation, despite the fact that an excess of hydroxyl ions is always present in the solution. This, in our opinion, again serves as evidence that both steps of reaction (2) proceed simultaneously, i.e., that the rate of the second step is greater than the rate of the first step. In contrast, reaction (3) goes as a first-order reaction in the initial period, which serves as evidence that both of its steps are consecutive reactions. This is also confirmed by potentiometric study [17]. The results of investigating the kinetics of the reaction prove to be in complete harmony with the kinetics data of Lewis and Suhr [5]. As a result, the validity of the new theory of the structure of diazo compounds was again confirmed by the spectral investigation results.

SUMMARY

1. Water solutions of diazo compounds exhibit characteristic selective light absorption in the ultraviolet region.

2. Different absorption bands are observed in acid and in alkaline media; in media where the pH ranges from 7 to 9 the absorption curves of different diazo compounds exhibit isobestic points.

3. The presence of isobestic points serves as evidence that in aqueous solutions, when equilibrium is established, the only compounds present are the diazo cation and the diazo anion.

4. Neutralization of the diazo cation with alkali is not a first-order reaction, which testifies to the faster rate of the second step of the reaction (dissociation of the diazo acid with the formation of the anion); neutralization of the diazo anion goes as a first-order reaction at the start; as a result, it is a consecutive reaction.

5. Processes going at a slow rate are present in the enumerated reactions: in the direct reaction the slow process is the initial reaction of the diazo cation with hydroxyl ion, while in the reverse reaction, it is the conversion of the nitrosamine to diazohydroxide and reaction of the latter with protons.

6. Water solutions of all of the investigated aromatic diazo compounds obey the Lambert-Beer (Bouguer) law in a wide pH range.

LITERATURE CITED

[1] E. Wolf, Z. Physik. Chem. B17, 46 (1932); H. C. Ramsberger, J. Am. Chem. Soc. 50, 123 (1928); A. E. Gillam and E. S. Stern, An Introduction to Electronic Absorption Spectroscopy in Organic Chemistry [Russian translation] (Moscow, IL, 1957), p. 89.

[2] A. Hantzsch, and J. Lifschitz, Ber. 45, 3011 (1912).

[3] J. Dobbie and C. Tinkler, J. Chem. Soc. 87, 273 (1905).

[4] R. Le Fevre and J. Sousa, J. Chem. Soc. 1957, 745.

[5] E. Lewis and H. Suhr, J. Am. Chem. Soc. 80, 1367 (1958).

[6] D. Anderson, R. Le Fevre, and J. Savage, J. Chem. Soc. 1947, 445.

[7] W. Sheppard and G. Sutherland, J. Chem. Soc. 1947, 453.

[8] R. Le Fevre, M. O'Dwyer, and R. Werner, Chem. and Ind. 1953, 378.

[9] M. Aroney, R. Le Fevre, and R. Werner, J. Chem. Soc. 1955, 276.

[10] K. Whetsel, G. Hawkins, and F. Johnson, J. Am. Chem. Soc. 78, 3360 (1956).

[11] L. Anderson and J. Steedly, J. Am. Chem. Soc. 76, 5144 (1954).

[12] G. Herzberg, Infrared and Raman Spectra of Polyatomic Molecules (New York, 1945).

[13] L. Anderson and M. Roedel, J. Am. Chem. Soc. 67, 955 (1945).

[14] H. Thompson, J. Chem. Soc. 1948, 328.

[15] J. Boyer, J. Am. Chem. Soc. 73, 5248 (1951).

[16] R. Le Fevre, J. Sousa, and R. Werner, J. Chem. Soc. 1954, 4686.

[17] B. V. Passet and B. A. Porai-Koshits, Trudy Leningrad. Tekhnolog. Inst. imeni Lensoveta. Raboty v Oblasti Khimii i Khimisheskoi Tekhnologii 46, 133 (1958).

[18] C. Wittwer and H. Zollinger, Helv. Chim. Acta 37, 1954 (1954).

[19] H. Zollinger, Chemie der Azofarbstoffe (Birkhäuser Verlag, Basel und Stuttgart, 1958).

[20] A. E. Gillam and E. S. Stern, An Introduction to Electronic Absorption Spectroscopy in Organic Chemistry [Russian translation] (Moscow, IL, 1957), p. 259.

CYANINE DYES

XII. SOME 5,5'-DIMETHOXY-6,6'-DIAMINOTHIACARBOCYANINES

I. I. Levkoev, N. N. Sveshnikov, N. S. Barvyn' and T. V. Krasnova

All-Union Motion-Picture Scientific Research Institute

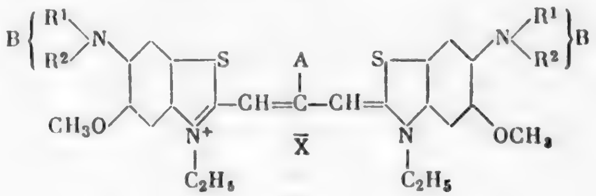
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 291-299, January, 1960

Original article submitted October 21, 1958

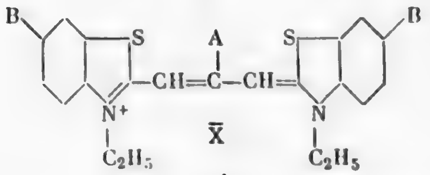
The introduction of electropositive groups into the heterocyclic residues of cyanine dyes deepens the color of the latter and the magnitude of the bathochromic displacement of the absorption maximum is mainly determined by the extent of the substituent's electronic reaction with the polymethyne chromophore [1-5]. With a change from 5,5'- or 6,6'-dimethyl- or dimethoxythiacarbocyanines to the corresponding 5,6,5',6'-tetrasubstituted derivatives there is a further additive displacement of the dye absorption maxima toward the longwave region of the spectrum [6, 7].

One might surmise that 5,6,5',6'-tetrasubstituted dyes of this series, containing polar amino groups in the hetero residues, would have an even deeper color. To test this hypothesis we condensed the quaternary salts of 2-methyl-5-methoxy-6-dimethylaminobenzthiazole [8] with orthoesters of carboxylic acids in pyridine (see [9]) and obtained 5,5'-dimethoxy-6,6'-bis(dimethylamino)-thiacarbocyanines [I, B = $(CH_3)_2N$].

However, it was found that in these dyes the effect of the substituents on the color was not additive and their absorption maxima were even displaced somewhat into the shortwave region as compared to those of 6,6'-bis(dimethylamino) derivatives [II, B = $(CH_3)_2N$] [4].



(I)



(II)

B = NH_2, CH_3NH, $(CH_3)_2N$, CH_3CONH, $CH_3CON(CH_3)$, p-$CH_3C_6H_4SO_2NH$ or p-$CH_3C_6H_4SO_2N(CH_3)$;
A = H, CH_3 or C_2H_5; X = acid residue.

A hypothesis was put forward that the anomalous color of these dyes was due to a decrease in electron displacement from the substituents to the polymethyne chromophore. However, the reasons for this phenomenon were not elucidated.

Continuing our investigations of similar tetrasubstituted dyes, we used the method mentioned above to synthesize a series of 5,5'-dimethoxy-6,6'-di(acylamino)thiacarbocyanines (I, $R^1 = H$ or CH_3, $R^2 = CH_3CO$ or p-$CH_3C_6H_4SO_2$) from the quaternary salts of the corresponding 2-methyl-5-methoxy-6-acylaminobenzthiazoles [8] and by heating the former with hydrochloric acid we obtained the 6,6'-diamino- and 6,6'-bis(methylamino) derivatives corresponding to them (I, $R^1 = H$ or CH_3, $R^2 = H$).

For comparison with the corresponding dyes of structure (I), we prepared, for the first time, 6,6'-bis(N-methyl-N-acetylamino) thiacarbocyanines and some 6,6'-di(p-toluenesulfonamido)- and 6,6'-bis(N-methyl-p-toluenesulfonamido) derivatives which were described briefly by A. I. Kiprianov and E. D. Sych [10]. The first of these dyes were synthesized by acetylating 6,6'-bis(methylamino)thiacarbocyanines or by condensing 2-methyl-6-N-methyl-N-acetylaminobenzthiazole ethyl-p-toluenesulfonate with orthoesters of carboxylic acids. The latter base was prepared by heating 2-methyl-6-N-methyl-p-toluenesulfonamidobenzthiazole with hydrochloric acid and acetylating the 6-methylamino derivative thus formed.

Table 1 gives the absorption maxima of the dyes synthesized (I and II, A = H) and of some other 6,6'-disubstituted thiacarbocyanines (in alcohol).

TABLE 1

Substituents in positions 6,6', B	Absorption max. (in mμ)			Displacement of λ_{max} in (I) vs. unsub. thiocarbocyanine (in mμ)	Additive displacement calc. for (I) (in mμ)	Deviation of λ_{max} of dye (I) from calc. value (in mμ)
	(I)	(II)				
		our data	literature data			
H	576	558	—	18	—	—
NH_2	616	594	596 [10, 11], 597 [2]	58	54	+ 4
CH_3NH	630	608	610 [2, 10]	72	68	+ 4
$(CH_3)_2N$	604	612	612 [10]	46	72	—26
CH_2CONH	598	577	581 [2, 10], 579 [11]	40	37	+ 3
$CH_3CON(CH_3)$	583	564	—	25	24	+ 1
p-$CH_3C_6H_4SO_2NH$	592	572	577 [2], 578 [10]	34	32	+ 2
p-$CH_3C_6H_4SO_2N(CH_3)$	585	568	570 [10]	27	28	— 1

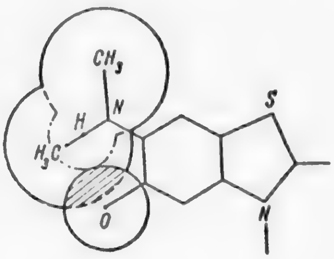
These data show that the introduction of methoxyl groups into the 5,5' positions of 6,6'-disubstituted thiacarbocyanines containing free or substituted amino groups produced a bathochromic displacement of the absorption maximum of all the dyes, except for 6,6'-bis(dimethylamino) derivatives. Both substituents in the hetero residue have an additive effect on the color and the calculated displacements of the absorption maxima agree well with those observed.

Thus, the lighter color of 5,5'-dimethoxy-6,6'-bis(dimethylamino)thiacarbocyanines could not be due to electrostatic interaction of the positive substituents in the ortho position, as $(CH_3)_2N$ and NH_2 or CH_3NH groups are quite similar to each other in this respect. However, these groups differ considerably in the volume they occupy and this, apparently, determines their different effect on the color of the dyes investigated. In ammonium salts with the structure $>\overset{+}{N}=C<$, the nitrogen, carbon, and atoms connected to them lie in one plane. As the electron density is displaced in aminocyanines from the R^1R^2N groups to the polymethyne chromophore, the nitrogen atom of the latter also becomes doubly bound to a certain extent. Under these conditions the substituents bound to the nitrogen atom should approach the plane of the hetero residue. Steric hinderance to such a disposition of the amino groups may arise in the presence of substituents in the ortho position and this would

result in a decrease in the interaction of the amino groups with the rest of the dye molecule. Evidently, such hindrance will be stronger the more the electron density is displaced from the nitrogen atom and the greater the volume of the substituents in the amino groups and in positions ortho to them.

A similar decrease in the interaction of $(CH_3)_2N$- and CH_3NH- groups with the benzene nucleus caused by steric hindrance is observed in the case of o-substituted dimethylanilines and o,o'-disubstituted monomethylanilines. The introduction of substituents into the ortho position produces a hypsochromic shift of the maximum of the first absorption band of these amines [12] and anomalous changes in their dipole moment and basicity [13] (see also [14]).

The electron displacement from the substituent to the main chromophore in 6,6'-bis(dimethylamino) thiacarbocyanines is apparently quite great, as the introduction of R_2N— groups in this case produces a very extensive bathochromic shift of the absorption maximum (55-60 mμ [2, 10, 15]). Thus, in these dyes the R_2N— groups apparently are quite deformed and the substituents connected to them lie relatively close to the hetero residue plane.



As an examination of their steric models shows, in the case of the corresponding 5,5'-dimethoxy derivatives [I, B = $(CH_3)_2N$], the location of $(CH_3)_2N$ groups in the same plane as the hetero residue is greatly hindered (see figure). Due to this, such dyes should have less electron interaction between the substituents and the polymethyne chromophore than in the case of dyes containing only dimethylamino groups in positions 6,6', and this is actually demonstrated by the lighter color of the former.

This conclusion is confirmed by the additive effect of the substituents on the color in 6,6'-diamino- and 6,6'-bis(methylamino)-5,5'-dimethoxythiacarbocyanines, in which no hindrance to a planar arrangement of the NH_2 or CH_3NH and CH_3O groups with the hetero residues is observed (see figure).

Thus, the anomalous color of 5,5'-dimethoxy-6,6'-bis(dimethylamino) thiacarbocyanines is apparently related to the fact that due to steric hindrance, the substituents in the dyes cannot be arranged in positions most favorable for their interaction with the main chromophore [16].

It is possible that for the same reasons there is no additive effect of the substituents on the color of the 7,7'-disubstituted 6,6'-bis(dimethylamino) thiacarbocyanines [17, 18] and 6,6'-diamino-5,5'-bis (dimethylamino) derivative [19] studied by A. I. Kiprianov and E. D. Sych. A. I. Kiprianov, I. N. Zhmurova, and I. K. Ushenko recently reached a similar conclusion on the effect of steric hindrance to a planar arrangement of a dimethylamino group with a benzene nucleus or a heterocyclic residue on the color of 5,5'- or 6,6'-bis (dimethylamino)-thiacarbocyanines containing methyl or tert-butyl groups in positions 6,6' or 5,5', respectively [11, 20], as well as some triphenylmethane [21] and azo dyes [21, 22].

In the 5,5'-dimethoxy-6,6'-bis(N-methyl-N-acylamino)-thiacarbocyanines (I, $R^1 = CH_3$, $R^2 = CH_3CO$ or p-$CH_3C_6H_4SO_2$) we investigated, the substituents also cannot be arranged in the same plane as the hetero residue without a change in valence angles. However, as the data in Table 1 show, the effect of the substituent groups on color is practically additive in these dyes. This phenomenon is evidently due to the fact that in dyes with acylamino groups the displacement of electron density from the latter to the main chromophore is quite insignificant (shift of λ_{max} by 6-10 mμ as compared with 54 mμ for dimethylamino derivatives); in connection with this they evidently retain the possibility of rotation about the C—N bond and the presence of CH_3O groups does not create steric hindrance to the normal interaction of substituents with the hetero residue. It is interesting that the presence of methyl and especially tert-butyl groups, which are more voluminous than an oxygen atom, in a position ortho to even an unsubstituted acetamido group produces an appreciable shift in the absorption maximum of the corresponding thiacarbocyanines toward the shortwave region (up to 9 mμ) [11, 20].

The data presented show that in examining the possibility of steric hindrance to the electron interaction of certain substituents with the main conjugated system, one should consider both the volume of the substituents and the extent of their possible interaction, which determines their position in space.

TABLE 2

Dye No.	Name of dye	Amount: base (in g)	Amount: p-toluene-sulfonic ester (in g)	Heating temp. and time	Orthoester and amount (in g)[e]	Amount: C_2H_5OH (in ml)	Amount: salt solution (in ml)
1	3,3'-Diethyl-5,5'-dimethoxy-6,6'-bis(dimethylamino)thiacarbocyanine iodide[a]	0.88	0.85	130—140°, 6 hours	E 1 (1.20)	10	20, 10% KI
2	3,3'-Diethyl-9-methyl-5,5'-dimethoxy-6,6'-bis(dimethylamino)thiacarbocyanine perchlorate	0.88	0.85	130—140, 6 hours	E 2 (1.30)	12	25, 20% $NaClO_4$
3	3,3',9-Triethyl-5,5'-dimethoxy-6,6'-bis(dimethylamino)thiacarbocyanine perchlorate	0.88	0.85	130—140, 6 hours	E 3 (1.41)	12	25, 20% $NaClO_4$
4	3,3'-Diethyl-5,5'-dimethoxy-6,6'-diacetamidothiacarbocyanine Br	0.24	0.21	135—145, 6 hours	E 1 (0.30)	7[c]	7, 10% KBr
5	3,3'-Diethyl-9-methyl-5,5'-dimethoxy-6,6'-diacetamidothiacarbocyanine bromide	0.24	0.21	135—145, 6 hours	E 2 (0.32)	7[c]	7, 10% KBr
6	3,3',9-Triethyl-5,5'-dimethoxy-6,6'-diacetamidothiacarbocyanine bromide	0.24	0.21	135—145, 6 hours	E 3 (0.35)	10	20, 20% KBr
7	3,3'-Dimethyl-9-ethyl-5,5'-dimethoxy-6,6'-diacetamidothiacarbocyanine bromide	0.24	0.20	130—140, 6 hours	E 3 (0.35)	12	25, 10% KBr
8	3,3'-Diethyl-5,5'-dimethoxy-6,6'-bis-(N-methyl-N-acetylamino)thiacarbocyanine iodide	0.25	0.21	130—140, 6 hours	E 1 (0.30)	5	10, 25% KI
9	3,3'-Diethyl-9-methyl-5,5'-dimethoxy-6,6'-bis(N-methyl-N-acetylamino)thiacarbocyanine iodide	0.25	0.21	130—140, 6 hours	E 2 (0.32)	5	10, 25% KI
10	3,3',9-Triethyl-5,5'-dimethoxy-6,6'-bis(N-methyl-N-acetylamino)thiacarbocyanine iodide	0.25	0.21	130—140, 6 hours	E 3 (0.35)	5	10, 25% KI
11	3,3'-Diethyl-5,5'-dimethoxy-6,6'-di(p-toluenesulfonamido)thiacarbocyanine bromide	0.70	0.44	120—130, 6 hours	E 1 (0.59)	20[c]	20, 10% KBr
12	3,3'-Diethyl-5,5'-dimethoxy-6,6'-bis-(N-methyl-p-toluenesulfonamido)thiacarbocyanine bromide	0.36	0.22	125—130, 6 hours	E 1 (0.30)	10	10, 10% KBr
13	3,3'-Diethyl-6,6'-bis(N-methyl-N-acetylamino)thiacarbocyanine[d]	0.22	0.22	140—150, 6 hours	E 1 (0.30)	1	2, 20% KI
14	3,3'-Diethyl-9-methyl-6,6'-bis(N-methyl-N-acetylamino)thiacarbocyanine perchlorate	0.22	0.22	140—150, 6 hours	E 2 (0.32)	2	45, 2% $NaClO_4$
15	3,3',9-Triethyl-6,6'-bis(N-methyl-N-acetylamino)thiacarbocyanine perchlorate	0.22	0.22	140—150, 6 hours	E 3 (0.26)	1	40, 5% $NaClO_4$
16	3,3'-Diethyl-6,6'-di(p-toluenesulfonamido)thiacarbocyanine p-toluenesulfonate	0.63	0.44	130, 6 hours	E 1 (0.60)	—	—
17	3,3'-Diethyl-6,6'-bis(N-methyl-p-toluenesulfonamido)thiacarbocyanine iodide	0.69	0.44	150—155, 2 hours	E 1 (0.60)	10	10, 10% KI

a. Perchlorate, dark-green prisms with m. p. 229-230°.

b. Before crystallization the dye was chromatographed on aluminum oxide in a chloroform solution.

c. Methanol.

d. Perchlorate, lustrous, bluish-gray prisms (from alcohol). M. p. 248-250°. Found %: N 9.14. $C_{27}H_{31}O_6N_4S_2Cl$. Calculated %: N 9.23.

e. E 1 - ethyl orthoformate, E 2 - ethyl orthoacetate, E3- ethyl orthopropionate; pyridine used — 3 ml for dye 14, 2.5 ml for dyes 16 and 17, 2 ml for the rest; dyes 1-3 and 8-10 heated for 45 minutes, the rest for 60 minutes.

Yield (%)	External appearance (crystallization solvent and amt. in ml per g of dye)	M. p.	Absorption maximum in C_2H_5OH (in mμ)	Found (%)	Formula	Calculated (%)
16[b]	Green prisms (50% alc., 20)	211—212°	604	I 19.67	$C_{27}H_{35}O_2N_4S_2I$	I 19.88
15[b]	Dark green prisms (50% alc., 25)	170	588	N 8.81, 8.86	$C_{23}H_{37}O_8N_4S_2Cl$	N 8.96
10[b]	Red-brown plates (50% alc., 30)	167—168	592	N 8.84, 8.76	$C_{29}H_{39}O_8N_4S_2Cl$	N 8.77
40	Blue needles (alc.,40)	270—272	598	Br 12.78	$C_{27}H_{31}O_4N_4S_2Br$	Br 12.90
26	Reddish brown prisms (alc.)	262—264	578	N 8.94, 8.99	$C_{28}H_{33}O_4N_4S_2Br$	N 8.85
19	Greenish blue needles (alc.)	215—216	582	Br 11.83	$C_{29}H_{35}O_4N_4S_2Br$	Br 11.90
35	Dark green needles (alc., 30)	243—245	578	N 9.17, 9.06	$C_{27}H_{31}O_4N_4S_2Br$	N 9.05
28	Bluish green prisms (alc., 150)	294—295	583	I 18.40, 18.43	$C_{29}H_{35}O_4N_4S_2I$	I 18.28
25	Blue prisms (alc., 170)	292—294	565	N 8.04, 7.92	$C_{30}H_{37}O_4N_4S_2I$	N 7.91
33	Blue prisms (alc.)	258—259	568	I 17.40, 17.34	$C_{31}H_{39}O_4N_4S_2I$	I 17.57
76	Violet prisms (CH_3OH,400)	210—212	592	N 6.70	$C_{37}H_{39}O_6N_4S_4Br$	N 6.64
48	Lustrous, green prisms (CH_3OH, 300)	250—252	585	N 6.52, 6.37	$C_{39}H_{43}O_6N_4S_4Br$	N 6.44
94	Lustrous, green prisms (alc., 33)	264—265	564	N 8.88	$C_{27}H_{31}O_2N_4S_2I$	N 8.83
48	Lustrous, dark green prisms (alc., 200)	232—234	552	N 9.03	$C_{28}H_{33}O_8N_4S_2Cl$	N 9.03
56	Violet prisms (alc., 80)	233—234	555	N 9.03	$C_{29}H_{35}O_8N_4S_2Cl$	N 8.83
74	Lustrous, blue-green prisms (CH_3OH, 200)	280—282	572	N 6.36	$C_{42}H_{42}O_7N_4S_5$	N 6.40
75	Lustrous, green prisms (alc., 140)	228—230	568	N 6.43	$C_{37}H_{39}O_4N_4S_4I$	N 6.52

The data in Table 1 also show that when the amino groups in 6,6'-bis(methylamino)thiacarbocyanines are acylated, there is a considerably greater hypsochromic shift in the absorption maximum than in the case of 6,6'-diamino derivatives (44 and 17 mμ for acetamido and 40 and 22 mμ, respectively, for p-toluenesulfonamido derivatives). Replacement of the hydrogen atoms at the nitrogen atoms of 6,6'-diacetamidothiacarbocyanine acetamido groups by methyl groups also produces an appreciable fall in the basicity of the dye. These observations indicate that there is definite intra- or intermolecular interaction between the hydrogen atom at the nitrogen and the oxygen atom of acylamino groups (see [23]) and as a result the electron acceptor nature of the acyl residue is appreciably decreased.

EXPERIMENTAL

2-Methyl-6-p-toluenesulfonamidobenzthiazole. To a solution of 3.28 g of 2-methyl-6-aminobenzthiazole in 16 ml of pyridine was added 4.08 g of p-toluenesulfonyl chloride. The mixture was heated for 1.5 hours in a flask with a reflux condenser on a boiling-water bath, then diluted with 200 ml of water, and 20 ml of hydrochloric acid added (d 1.19). The precipitate was collected by filtration and washed with water. The yield was 6.30 g (99 %). The m. p. was 204°. Recrystallization from alcohol gave slightly gray prisms with m. p. 209 to 210° (204° [10]).

2-Methyl-6-N-methyl-p-toluenesulfonamidobenzthiazole. Over a period of 15 minutes 2.52 g of dimethyl sulfate was added with stirring to a filtered solution of 3.18 g of 2-methyl-6-p-toluenesulfonamidobenzthiazole and 0.8 g of sodium hydroxide in 20 ml of water at 20-25°. After 30 minutes, a solution of 0.4 g of sodium hydroxide in 10 ml of water was added and the precipitate collected and washed with water. The yield was 2.45 g (73%). The m. p. was 149-150°. The substance formed slightly yellow needles (from alcohol, 1 g from 20 ml). The m. p. was 160-160.5° (150-160° [10]).

2-Methyl-6-methylaminobenzthiazole. A solution of 3.32 g of the previous compound in 40 ml of hydrochloric acid (d 1.17) was boiled in a flask with a reflux condenser for 2 hours, then diluted with 100 ml of water and made alkaline with a 30% solution of sodium hydroxide. The precipitate was collected and washed with water. The weight was 1.55 g. The m. p. was 92-93°. A further 0.15 g of substance was extracted from the filtrate with ether. The total yield was 1.70 g (95%). The substance formed colorless platelets (from ligroin). It had m. p. 94-95°. It was readily soluble in alcohol, benzene, ether, and acetone, and more difficultly so in ligroin.

Found %: N 15.68. $C_9H_{10}N_2S$. Calculated %: N 15.73.

The picrate formed orange prisms (from alcohol). The m. p. was 182-183°.

2-Methyl-6-N-methylacetamidobenzthiazole. A mixture of 1.07 g of 2-methyl-6-methylaminobenzthiazole and 0.82 g of acetic anhydride was heated for 30 minutes on a boiling-water bath, diluted with 20 ml of water and made alkaline with potassium carbonate when cool,to precipitate a colorless oil which gradually crystallized. The precipitate was collected and washed with 10 ml of water. The weight was 1.00 g. The m. p. was 102-104°. Extraction of the filtrate with ether and washing the extract yielded a further 0.25 g of base with m. p. 98-100°. The total yield was 1.25 g (94%). For purification, the product was mixed with ether (0.5 g with 2 ml), collected by filtration and recrystallized twice from ligroin (0.3 g from 3 ml). The colorless platelets had m. p. 105-106°. The substance was quite readily soluble in water, very readily soluble in alcohol, benzene, and acetone, and less so in ether and ligroin.

Found %: N 12.67. $C_{11}H_{12}ON_2S$. Calculated %: N 12.73.

6,6'-Diacylamino-, 5,5'-dimethoxy-6,6'-diacylamino-, and 6,6'-bis(dimethylamino)-thiacarbocyanines. These dyes were prepared by heating the corresponding substituted 2-methylbenzthiazoles with ethyl or methyl p-toluenesulfonates for several hours in a flask with a reflux condenser on an oil bath. Pyridine and the ortho-ester of carboxylic acid were added to the quaternary salt obtained and the mixture was heated for a definite time on an oil bath at 130-135°. The reaction mass was then diluted with ether, the tarry precipitate dissolved in ethyl or methyl alcohol, and the dye isolated by the addition of an aqueous solution of potassium bromide or iodide,or sodium perchlorate. The 3,3'-diethyl-6,6'-di-(p-toluenesulfonamido)thiacarbocyanine was isolated as the p-toluenesulfonate, which precipitated when the reaction mixture cooled.

The dyes were purified by careful washing with water and alcohol and recrystallization from ethyl or methyl alcohol until a constant melting point was obtained. Some preparations were purified before recrystallization by chromatography on aluminum oxide in a chloroform solution. Before analysis, the dyes were dried to constant weight in vacuum at 80-100°.

The conditions for the preparation and the yields of the dyes, their properties and analysis results are given in Table 2.

3,3'-Diethyl-6,6'-bis(methylamino)thiacarbocyanine iodide. A sample of 1.00 g of 3,3'-diethyl-6,6'-bis-(N-methyl-p-toluenesulfonamido) thiacarbocyanine iodide was dissolved in 50 ml of 33% hydrochloric acid and the mixture boiled in a flask with a reflux condenser for 1 hour. The solution was diluted with 200 ml of water, 10 g of potassium iodide added, and the mixture neutralized with aqueous ammonia. The precipitate was collected and washed with water, alcohol, and ether. The yield was 0.41 g (65%). The dye was purified by chromatography on aluminum oxide in a chloroform solution and then recrystallized twice from alcohol (1 g from 200 ml). The substance formed lustrous, dark-blue prisms (containing 1 mole of C_2H_5OH). The m. p. was 240-242° (243.5° [10]).

Found %: N 9.32, 9.30. $C_{23}H_{27}N_4S_2I \cdot C_2H_5OH$. Calculated %: N 9.40.

3,3'-Diethyl-5,5'-dimethoxy-6,6'-diaminothiacarbocyanine iodide. This was prepared similarly to the above dye by boiling (20 minutes) the bromide of the 6,6'-diacetamido derivative (0.40 g) with 20% hydrochloric acid (5 ml). The liquid was diluted with 10 ml of potassium iodide solution and the mixture neutralized with ammonia. The yield was 0.35 g (93%). Chromatography of the substance on aluminum oxide and two recrystallizations from alcohol (1 g from 425 ml) yielded lustrous, dark-blue prisms (with 1 mole of C_2H_5OH) with m. p. 230-232°.

Found %: N 9.15, 9.04. $C_{23}H_{27}O_2N_4S_2I \cdot C_2H_5OH$. Calculated %: N 8.92.

3,3'-Diethyl-5,5'-dimethoxy-6,6'-bis(methylamino)thiacarbocyanine iodide was prepared by boiling a solution of 0.60 g of 3,3'-diethyl-5,5'-dimethoxy-6,6'-bis(N-methyl-p-toluenesulfonamido) thiacarbocyanine bromide in 30 ml of 37% hydrochloric acid (30 minutes). The liquid was diluted with a solution of 5 g of potassium iodide in 150 ml of water and neutralized. The yield was 0.30 g (78%). Purification of the product as above and recrystallization from alcohol (1 g from 375 ml) gave dark green prisms (with 1 mole of C_2H_5OH) with m. p. 210-212°

Found %: N 8.60, 8.69. $C_{25}H_{31}O_2N_4S_2I \cdot C_2H_5OH$. Calculated %: N 8.54.

3,3'-Diethyl-6,6'-bis(N-methyl-N-acetylamino) thiacarbocyanine iodide. A sample of 0.6 g of 3,3'-diethyl-6,6'-bis(methylamino) thiacarbocyanine iodide was heated with 2 ml of acetic anhydride on an oil bath at 115-120° for 15 minutes. On cooling, the liquid was diluted with ether (50 ml), the tarry mass dissolved in 2 ml of alcohol, and 10 ml of a 10% potassium iodide solution added, but no precipitate formed. The solution was extracted with chloroform, the extract dried with sodium sulfate, and the chloroform removed in vacuum. The weight was 0.60 g (86%). The lustrous green prisms had m. p. 264-265° (1 g from 30 ml of alcohol). A mixed melting point with the dye prepared from 2-methyl-6-N-methyl-N-acetylaminobenzthiazole was not depressed (see Table 2).

3,3'-Diethyl-5,5'-dimethoxy-6,6'-bis(N-methyl-N-acetylamino) thiacarbocyanine iodide. This was prepared analogously to the previous dye by heating the iodide of the corresponding methylamino derivative (0.08 g) with acetic anhydride (0.8 ml) at 140° (15 minutes). After the solution had been treated with ether the precipitate was dissolved in alcohol (2 ml) and the dye isolated by the addition of 10% potassium iodide solution (2 ml). The yield was 0.08 g (88%). The substance formed bluish-green prisms (from alcohol). The m. p. was 294-295°. A mixed melting point with the dye prepared from 2-methyl-5-methoxy-6-N-methyl-N-acetylaminobenzthiazole was not depressed (see Table 2).

The absorption spectra of all the dyes in a $1 \cdot 10^{-4}$ M alcohol solution were measured on an SF-2 spectrophotometer.

SUMMARY

1. A series of symmetrical 5,5'-dimethoxythiacarbocyanines, containing free or substituted amino groups in the 6,6' positions, and also some 6,6'-p-toluenesulfamido and 6,6'-bis(N-methyl-N-acylamino) substituted dyes of this class were synthesized.

2. It was shown that in these dyes all the above-mentioned substituents, with the exception of dimethylamino groups, have an additive effect on the color.

Apparently, the lighter color of 5,5'-dimethoxy-6,6'-bis(dimethylamino)thiacarbocyanines is connected with steric hindrance to a planar disposition of the hetero residues and substituents,and as a result the interaction of the latter with the main chromophore decreases.

Steric hindrance to electron interaction of various groups depends not only on the volume of the latter, but also on the extent of this interaction, which may alter the disposition of the groups in space.

3. It was noted that in thiacarbocyanines, acylation of methylamino groups in hetero residues produced a considerably greater hypsochromic shift of the absorption maximum and a greater decrease of the dye's basicity than in the case of acylation of amino groups. In this connection, a hypothesis was put forward that the weaker electron acceptor character of the acyl residue in the acylamino group is due to the formation of an intra- or intermolecular hydrogen bond.

LITERATURE CITED

[1] A. I. Kiprianov, Jubilee Coll. Acad. Sci. Ukr. SSR [In Russian] (1944), p. 257.

[2] A. I. Kiprianov, I. K. Ushenko, and E. D. Sych, Zhur. Obshchei Khim. 15, 200 (1945).

[3] A. I. Kiprianov, Jubilee Coll. Acad. Sci. Ukr. SSR [In Russian] (1947), p. 27.

[4] I. I. Levkoev, N. N. Sveshnikov, I. N. Gorbacheva, and A. F. Vompe, Tr. NIKFI 7, 25 (1944).

[5] I. I. Levkoev, N. N. Sveshnikov, E. Z. Kulik, and T. V. Krasnova, Zhur. Obshchei Khim. 27, 3097 (1957).*

[6] I. I. Levkoev, A. F. Vompe, N. N. Sveshnikov, and N. S. Barvyn', Zhur. Obshchei Khim. 22, 879 (1952).*

[7] I. I. Levkoev, Z. P. Sytnik, S. V. Natanson, V. V. Durmashkina, T. V. Krasnova, and R. S. Shuser, Zhur. Obshchei Khim. 24, 2034 (1954).*

[8] I. I. Levkoev, N. N. Sveshnikov, I. N. Gorbacheva, N. S. Barvyn', and T. V. Krasnova, Zhur. Obshchei Khim. 24, 280 (1954).*

[9] F. M. Hamer, J. Chem. Soc. 1927, 2798; 1928, 3160.

[10] A. I. Kiprianov and E. D. Sych, Zap. Inst. Khimii Akad. Nauk Ukr. SSR 8, 103 (1946).

[11] A. I. Kiprianov and I. N. Zhmurova, Zhur. Obshchei Khim. 23, 493 (1953).*

[12] W. R. Remington, J. Am. Chem. Soc. 67, 1838 (1945).

[13] N. F. Hall and M. R. Sprinkle, J. Am. Chem. Soc. 54, 3469 (1932); L. P. Hammett, and M. A. Paul, ibid. 56, 827 (1934); C. E. Ingham and G. C. Hampson, J. Chem. Soc. 1939, 981; J. Fischer, Acta Chem. Scand. 4, 1197 (1950).

[14] A. I. Kiprianov and I. N. Zhmurova, Usp. Khim. 22, 1246 (1953).

[15] A. I. Kiprianov and E. D. Sych, Tr. Inst. Khim. KhGU 2, 15 (1936).

[16] I. I. Levkoev, N. N. Sveshnikov, and N. S. Barvyn', Doklady Akad. Nauk SSSR 85, 805 (1952).

[17] A. I. Kiprianov and E. D. Sych, Collection Sci. Work Inst. Org. Chem. Acad. Sci. USSR [In Russian] 13, 17 (1947).

* Original Russian pagination. See C. B. translation.

[18] E. D. Sych, Ukr. Khim. Zhur. 14, 45 (1948).

[19] E. D. Sych, Ukr. Khim. Zhur. 18, 148 (1952).

[20] A. I. Kiprianov and I. N. Zhmurova, Doklady Akad. Nauk SSSR 85, 789 (1952).

[21] A. I. Kiprianov and I. K. Ushenko, Izvest. Akad. Nauk SSSR, Otdel Khim. Nauk 492 (1950).

[22] A. I. Kiprianov and I. N. Zhmurova, Zhur. Obshchei Khim. 23, 626 (1953).*

[23] P. W. Vittum and G. H. Brown, J. Am. Chem. Soc. 68, 2235 (1946).

* Original Russian pagination. See C. B. translation.

REACTION OF ACETYL PEROXIDE WITH MERCURIC ACETATE AND SOME MERCURIC SALTS OF INORGANIC ACIDS

Yu. A. Ol'dekop and N. A. Maier

Institute of Chemistry, Academy of Sciences, Belorus. SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 299-302, January, 1960

Original article submitted September 25, 1958

In previous reports [1-3], we investigated the reaction of mercuric acetate with acetyl, benzoyl, and meta-nitrobenzoyl peroxides and some other initiators of radical processes. It was shown that when treated with peroxides, mercuric acetate underwent chain decomposition to form methylmercury compounds in quantitative yield. In the present work we continued our study of the decomposition of mercuric acetate by acetyl peroxide in order to obtain new data on the reaction mechanism. In addition, we investigated the reaction of acetyl peroxide with some mercury salts of inorganic acids.

EXPERIMENTAL

Chemically pure grade acetic acid was used without further purification. "Pure" grade mercuric acetate was used. Analytically pure grade mercuric sulfate, chloride, and iodide, and mercurous sulfate and chloride were used. An acetic acid solution of acetyl peroxide, with a concentration of 15-16%, was prepared by the procedure we described previously [2]. The peroxide content of the solution was determined iodometrically [4] before each experiment.

1. The reaction of mercuric acetate with acetyl peroxide in acetic acid at 97-98° was carried out in a three-necked 250 ml flask fitted with a reflux condenser, a dropping funnel, which also served as a bubbler for passing air through the system, and a stirrer with a seal. A spiral trap, cooled with a mixture of solid carbon dioxide and acetone, and three absorption tubes with potassium hydroxide were connected to the top of the reflux condenser. The gases passing through the system were collected in gas burettes.

A solution of acetyl peroxide was added rapidly to a heated mixture of 9.6 g (0.03 mole) of mercuric acetate and 100 ml of acetic acid. Heating and stirring was continued for 2-2.5 hours (gas evolution ceased 90-100 minutes after the addition of the solution). The accumulation of gases in the burettes with time was measured.

At the end of the reaction, CO_2 and moisture-free air was blown through the system to flush the gaseous products into the burette. The carbon dioxide yield was determined from the increase in weight of the potassium hydroxide absorption tubes. Small amounts of unabsorbed carbon dioxide were generally present in the gas collected. These amounts were also taken into account. The experimental results are given in the table. The gas was analyzed with a VTI-2 gas analyzer and a Kh-1M chromothermographic gas analyzer of the Gor'kii Scientific Research Institute of Chemistry.

The reaction mixture was a colorless solution; in some experiments the mixture contained a precipitate of mercurous acetate and also traces of metallic mercury. The precipitate was collected and washed with acetic acid. Tests were carried out with KCl, KI, and NH_4OH to confirm the presence of Hg_2^{++} ion and the absence of Hg^{++} ion. A test for acetate ion (formation of ethyl acetate) was carried out in individual experiments.

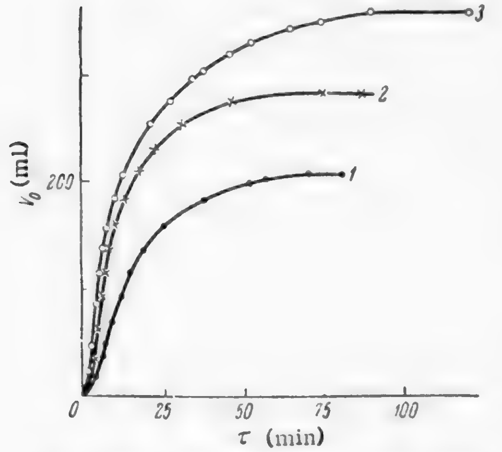
Acetic acid was removed from the solution in vacuum. The residue was dissolved in water, the solution filtered and KI added to it. The CH_3HgI precipitate was washed with water; the m. p. was 143-144° (from alcohol and ether); a mixed melting point with pure methylmercuric iodide was not depressed. Small amounts of methyl acetate, which was identified by its physical constants, collected in the spiral trap.

Reactions of Mercuric Acetate with Acetyl Peroxide in Acetic Acid at 97-98°

Acetyl peroxide taken for reaction*		Obtained after reaction							$\frac{\Delta V_0}{\Delta \tau}$ (ml/min)
		CH_3HgI		mercurous acetate		CO_2	CH_4	C_2H_6	
g	mole	g	% of original mercury salt	g	% of original mercury salt	mole			
0.59	0.005	9.5	93.0	0.3	3.84	0.0284	0.0021	0.0026	9.83
0.885	0.0075	9.6	93.7	0	0	0.0373	0.0063	0.0023	23.5
1.18	0.01			0	0	0.0429	0.0092	0.0027	26.4
1.18	0.01	9.8	95.4	0	0	0.0401	0.0085	0.0023	

* In all experiments 9.6 g (0.03 mole) of mercuric acetate and 100 ml of acetic acid were taken.

In all experiments the yields of methylmercury compounds were close to quantitative (93-95%) and no mercuric acetate was found in the reaction products; a small amount (3.8% yield) of mercurous acetate was present only when 0.005 mole of acetyl peroxide was used, but none was formed with greater amounts of peroxide; a small amount of methyl acetate was also found.



The effect of the amount of original acetyl peroxide on the rate of evolution of saturated hydrocarbons. Acetyl peroxide (in moles): 1) 0.005; 2) 0.0075; 3) 0.01.

The gas evolved consisted of CO_2, methane, and ethane. The amount of CO_2 increased with an increase in the amount of acetyl peroxide, but not proportionately; with double the amount of peroxide the CO_2 yield increased only by a factor of 1.4; at the same time the amount of methane increased by a factor of 4. The ethane yield did not depend on the amount of peroxide taken. The amounts of methane and ethane were of the same order. With 0.005 mole of peroxide the methane and ethane yields were practically the same.

We previously studied the total gas evolution rate [1, 2]. Here, we investigated the evolution rate of hydrocarbon gases. An examination of the kinetic curves (see figure) shows that the reaction rate (the value $\frac{\Delta V_0}{\Delta \tau}$) with respect to the sum of the methane and ethane depended on the amount of acetyl peroxide: An increase in the amount of peroxide in a ratio of 1.0 : 1.5 : 2.0 produced an increase in the hydrocarbon evolution rate in a ratio of 1.0 : 2.4 : 2.7, respectively. This relation is similar to the previously established [1, 2] relation of the total gas formation rate to the amount of acetyl peroxide. The form of the curves for hydrocarbon yield is the same as that for the total gas yield; a linear section is clearly seen in both cases.

2. Reaction of mercuric sulfate with acetyl peroxide in acetic acid at 97-98°. Over a period of 10-15 minutes 12.0 g of an acetyl peroxide solution (approximately 2.4 g of pure peroxide, or 0.02 mole) was added to a mixture of 30.0 g of $HgSO_4$ and 150 ml of acetic acid at room temperature with constant mixing. The

mixture was then heated on a boiling-water bath for 6 hours, by which time a test for peroxide was negative. The reaction mixture was filtered and the precipitate divided into two parts by decantation. First part: 1.02 g of Hg_2SO_4 (test for Hg_2^{++} and SO_4^{--}), 4.05% yield on mercury salt; second part: 26.78 g of $HgSO_4$ (test for Hg^{++} and SO_4^{--}), 89.3% yield on mercury salt.

The filtrate was diluted with water to 500 ml. KI was added to 200 ml of the solution to precipitate 0.21 g of CH_3HgI, with m. p. 144°. A mixed melting point was not depressed. The yield was 7.67% on the acetyl peroxide taken.

3. The reaction of mercuric chloride with acetyl peroxide in acetic acid at 97-98° was carried out as described in 2. We took 9.9 g of $HgCl_2$, 10 g of acetyl peroxide solution (2.04 g of pure peroxide) and 150 ml of acetic acid.

Filtration of the cooled reaction mixture yielded 0.18 g of mercuric chloride (test for Hg^{++} and Cl^- ions). Only Hg^{++} and Cl^- ions were detected in the solution; no methylmercury derivatives or mercurous salts were found.

4. The reaction of mercuric iodide with acetyl peroxide in acetic acid at 97-98° was carried out as described in 2. We took 15.0 g of HgI_2, 10.0 g of acetyl peroxide solution (2.04 g of pure peroxide), and 150 ml of acetic acid.

After cooling, the reaction mixture was filtered. A red precipitate of HgI_2 remained on the filter; its weight was 11.4 g (76.0% of starting salt). The filtrate was diluted with water to 500 ml. KI was added to 250 ml of the solution to precipitate 0.29 g of CH_3HgI with m. p. 143-144° (from acetone). A mixed melting point with pure methylmercuric iodide was not depressed. The yield was 9.8% on the acetyl peroxide taken.

5. The reaction of mercurous sulfate with acetyl peroxide in acetic acid at 97-98° was carried out as described in 2. We took 10.0 g of Hg_2SO_4, 10.0 g of acetyl peroxide solution (2.5 g of pure peroxide) and 150 ml of acetic acid.

The cooled reaction mixture yielded a precipitate of 8.83 g of mercurous sulfate (test for Hg_2^{++} and SO_4^{--}). The yield was 88.3% of the original salt. Traces of metallic mercury were also detected. The filtrate was diluted with water to 500 ml. KI was added to 200 ml of solution. We obtained a precipitate of 0.28 g of CH_3HgI with m. p. 143-144°. A mixed melting point with pure methylmercuric iodide was not depressed. The yield was 9.65% on the acetyl peroxide taken.

6. The reaction of mercurous chloride with acetyl peroxide in acetic acid at 97-98° was carried out as described in 2. We took 10.0 g of Hg_2Cl_2, 10.0 g of acetyl peroxide solution (2.5 g of pure peroxide) and 150 ml of acetic acid.

The reaction mixture yielded 9.32 g of mercurous chloride (test for Hg_2^{++} and Cl^-). The filtrate yielded 0.06 g of CH_3HgI (m. p. 143°). The yield was 0.83% on the acetyl peroxide taken.

SUMMARY

1. Acetyl peroxide reacted with mercuric acetate in acetic acid to give the following reaction products: methylmercuric acetate, carbon dioxide, methane, and ethane. The methylmercuric acetate yields were very close to quantitative.

2. The reactions of acetyl peroxide with mercuric sulfate, chloride, and iodide and with mercurous sulfate and chloride were investigated. The formation of small amounts of methylmercury compounds in all cases, except for that of mercuric chloride, was demonstrated.

LITERATURE CITED

[1] G. A. Razuvaev, Yu. A. Ol'dekop, and N. A. Maier, Doklady Akad. Nauk SSSR 98, 613 (1954).

[2] G. A. Razuvaev, Yu. A. Ol'dekop, and N. A. Maier, Zhur. Obshchei Khim. 25, 697 (1955).*

[3] G. A. Razuvaev, and Yu. A. Ol'dekop, Tr. po Khim. i Khim. Tekhnol., (Gor'kii) 1, 178 (1958).

[4] W. S. Smit, Rec. trav. chim. 49, 675 (1930).

* Original Russian pagination. See C. B. translation.

PHOTOCHEMICAL REACTIONS OF MERCUROUS ACETATE AND MERCURIC ACETATE AND PROPIONATE

Yu. A. Ol'dekop and N. A. Maier

Institute of Physicoorganic Chemistry, Academy of Sciences, Belorus. SSR

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 303-307, January, 1960

Original article submitted January 14, 1959

G. A. Razuvaev and one of us have previously described the photodecarboxylation of mercuric acetate, propionate [1], and benzoate [2] in certain solvents at the boiling points of the latter with the formation of organometallic compounds of the type RHgOCOR. Their yields depended on the nature of the solvent. However, the data given were of a preliminary character. In the present work, we investigated the photochemical reactions of mercuric acetate in benzene, acetic acid and mixtures of them; of mercurous acetate in acetic acid; and mercuric propionate in benzene and propionic acid. The reactions were carried out in boiling solvent.

It was noted in [1] that even after mercuric acetate had been irradiated in boiling benzene for 8 hours, only a small part of the starting salt was decarboxylated. The bulk of the mercuric acetate remained unchanged. In the present work, we achieved complete reaction by stirring the whole reaction mixture; there was no original mercuric acetate in the reaction products and the yield of methylmercuric acetate was 34%. The second product was mercurous acetate (about 62%). The gas evolved was found to contain CO_2, methane, ethane, and carbon monoxide. Metallic mercury and benzene mercuration products were absent (see table).

Experiment 3 was carried out in an atmosphere of CO_2 in order to elucidate the effect of air on the course of the photoreaction. The results were practically the same; only a slight decrease in the methane yield and an increase in CO yield was noted.

The course of the photoreaction of mercuric acetate in benzene was followed by the evolution of gas. The irradiation was continued until gas evolution ceased. If irradiation was stopped in the middle of the process (experiment 4) the evolution of gas also ceased, although the reaction mixture continued to boil; a considerable portion of the starting mercury salt had not reacted. The yields of all the reaction products were lower than when irradiation was continued until gas evolution ceased.

The data obtained indicate that under the experimental conditions methylmercuric acetate and mercurous acetate are stable to irradiation in boiling benzene.

The addition of acetic acid to the benzene promoted photodecarboxylation of mercuric acetate so that the reaction time fell and the methylmercuric acetate yield increased (with a corresponding decrease in the mercurous acetate yield). Metallic mercury was present in the reaction products. The addition of a larger amount of acetic acid produced a greater change in the reaction in the given direction (experiments 5 and 6).

Irradiation of mercuric acetate in boiling acetic acid gave a 66% yield of methylmercuric acetate. The other reaction products were metallic mercury (31.6%), CO_2, methane, ethane, and CO (experiment 7). No mercuric and mercurous acetates were present. If irradiation was stopped when original mercuric acetate was still present in the reaction mixture, gas evolution continued for some time after the lamp was switched off (the mixture was kept boiling). The methylmercuric acetate and gaseous reaction product yields were somewhat

lower in this experiment (No. 8) than in experiment 7; 35% of the mercuric acetate did not react. Metallic mercury was absent. The mercurous acetate yield was 10.5%.

A comparison of the mercurous acetate yields in experiments 7 and 8 indicates that the mercurous acetate first formed decomposed under further irradiation in acetic acid. We investigated the photoreaction of mercurous acetate in acetic acid in order to study the decomposition of the acetate. Methylmercuric acetate and metallic mercury were found in the reaction products; the gas evolved consisted of CO_2, methane, ethane, and CO. A comparison of the methylmercuric acetate and metallic mercury yields in experiments 9 and 10 indicate that the methylmercuric acetate formed in the reaction decomposed under further irradiation to yield metallic mercury. In this case, an increase in gaseous products was observed.

Photochemical Reactions of Mercurous Acetate and Mercuric Acetate and Propionate

Expt. No.	Medium (ml)		Obtained after reaction (yields)										Irradiation time (in min)
	benzene	acid	Hg salts (II)	Hg salts (I)	mercury	alkylmercuric salt	CO_2	CH_4	C_2H_6	C_2H_4	C_4H_{10}	CO	
			in %				in mole						
Reaction of 9.6 g (0.03 mole) of mercuric acetate in benzene, acetic acid and mixtures of them													
1	150	—	0	64.3	0	32.6	0.0271	0.0026	0.0022	—	—	0.0002	400
2	150	—	0	61.7	0	34.2	0.0257	0.0025	0.0017	—	—	0.0002	520
3	150	—	0	67.4	0	32.1	— *	0.0015	0.0012	—	—	0.0003	330
4	150	—	38.7	37.5	0	23.6	0.0163	0.0012	0.0014	—	—	0.0001	155
5	135	15	0	45.9	2.16	48.8	0.0243	0.0017	0.0013	—	—	0.0002	265
6	100	50	0	33.4	3.32	61.5	0.022[illegible]	0.0037	0.0010	—	—	0.0002	270
7	—	150	0	0	31.6	66.0	0.0211	0.0043	0.0005	—	—	0.0002	180
8	—	150	35.0	10.5	0	53.1	0.0129	0.0006	0.0004	—	—	traces	7
Reaction of 7.8 g (0.015 mole) of mercurous acetate in acetic acid													
9	—	150	0	0	81.0	14.1	0.0173	0.0103	0.0008	—	—	0.0004	240
10	—	150	0	0	63.6	32.1	0.0122	0.0027	0.0001	—	—	0.0002	135
11	—	150	traces	18.0	42.7	36.9	0.0057	0.0001	0.0003	—	—	0.0001	90
Reaction of 10.4 g (0.03 mole) of mercuric propionate in benzene and in propionic acid													
12	150	—	0	71.1	0	26.9	0.0248	—	0.0033	0.0012	0.0027	0.0002	180
13	150	—	0	68.3	0	30.3	0.0240	—	0.0031	0.0013	0.0022	0.0002	210
14	—	150	0	0	84.0	13.5	0.0194	—	0.0119	0.0009	0.0006	0.0004	270
15	—	150	0	0	46.0	50.4	0.0116	—	0.0018	0.0004	0.0003	0	105
16	—	150	0	0	29.1	68.0	0.0054	—	0.0006	0.0001	0.0002	0	80
17	—	150	24.1	26.9	11.1	36.4	0.0054	—	0.0004	traces	traces	0	45

* Experiment 3 was carried out in an atmosphere of CO_2.

When the mercurous acetate was irradiated for a shorter time (experiment 11), a considerable part of the original salt (18%) did not react. The metallic mercury yield was less and that of methylmercuric acetate greater than in experiments 9 and 10. Mercuric ions were also detected in the reaction products.

The same general rules as observed for mercuric acetate applied to the irradiation of mercuric propionate in benzene and in propionic acid. The photoreaction of mercuric propionate in benzene gave ethylmercuric propionate (approximately 30%) and mercurous propionate (68%). They were stable to further irradiation in benzene (under the experimental conditions); after 3-3.5 hours irradiation, gas evolution ceased. The gas contained CO_2, ethane, ethylene, butane, and carbon monoxide (experiments 12 and 13).

Irradiation of mercuric propionate in propionic acid gave metallic mercury and ethylmercuric propionate. The yield of the latter reached 68%. The same products were found in the gas as from the reaction in benzene (see table). The formation of CO was observed only after prolonged irradiation. With a shorter irradiation period, the reaction products contained the starting mercuric propionate and mercurous propionate (experiment 17). A comparison of the yields of ethylmercuric propionate, mercurous propionate, and metallic mercury in experiments 14-17 indicates that when irradiated further in propionic acid, ethylmercuric propionate and mercurous propionate decomposed to form metallic mercury.

On the basis of the products obtained, the course of the reactions studied may be represented by the following scheme:

$$RCOOHgOCOR \xrightarrow{h\nu} RCOO\cdot + \cdot HgOCOR \quad (R = CH_3 \text{ or } C_2H_5) \tag{1}$$

$$RCOO\cdot \longrightarrow R\cdot + CO_2 \tag{2}$$

$$R\cdot + \cdot HgOCOR \longrightarrow RHgOCOR \tag{3}$$

$$R\cdot + RCOOHgOCOR \longrightarrow RHgOCOR + RCOO\cdot \tag{4}$$

$$R\cdot + R'H \longrightarrow RH + R'\cdot \tag{5}$$

(where R'H = a hydrogen-containing compound)

$$2R\cdot \longrightarrow R{-}R \tag{6}$$

$$2R\cdot \longrightarrow R_{+H} + R_{-H} \quad (\text{for } R = C_2H_5) \tag{7}$$

$$2\cdot HgOCOR \longrightarrow Hg_2(OCOR)_2 \tag{8}$$

$$Hg_2(OCOR)_2 \xrightarrow{h\nu} Hg + Hg(OCOR)_2 \tag{9}$$

When irradiated, a diacyloxymercury molecule decomposes to give RCOO· and ·HgOCOR radicals. At a high temperature the acyloxy radical decomposes to CO_2 and an alkyl radical [3] [by Eq. (2)]. An alkylmercuric salt may form by the combination of R· and ·HgOCOR radicals. The radical R· may react with diacyloxymercury by Eq. (4), producing chain decomposition of the latter [4, 5]; the existence of such a reaction is confirmed by the fact that gas was evolved after irradiation had been stopped. An alkyl radical may abstract hydrogen from the solvent or mercury salt [Eq. (5)] to form the corresponding alkanes (methane or ethane) and may also dimerize to give ethane or butane [Eq. (6)]. An ethyl radical may disproportionate to give ethane and ethylene [Eq. (7)]. Two ·HgOCOR radicals dimerize to give the corresponding mercurous salt. The mercurous salt undergoes photolysis in an acid medium (acetic or propionic) to form metallic mercury and a mercuric salt [Eqs. (8) and (9)].

The fact that the yield of alkylmercuric salt in the presence of acid was higher than in benzene may be explained in the same way as before [6].

The formation of carbon monoxide in the reactions described may be explained, apparently, by decomposition of the acyloxy radical [7].

$$RCOO\cdot \longrightarrow RCO\cdot + {}^1/_2O_2 \tag{10}$$

$$RCO\cdot \longrightarrow R\cdot + CO \tag{11}$$

EXPERIMENTAL

The experiments were carried out in a quartz flask with a reflux condenser and a bubbler. A quartz tube, in which was placed a PRK-4 mercury-quartz lamp, was sealed horizontally into the flask. An amount of mercury salt equivalent to 0.03 g-at of mercury and 150 ml of solvent were placed in the flask; the level of the reaction mixture was above the inserted tube. The mixture was heated to boiling and the PRK-4 lamp then switched on (the voltage was kept constant within ± 3 v). The heat evolved by the lamp was sufficient to keep

the solvent boiling; however, to ensure mixing of the whole mass, external heating was not eliminated completely but only reduced. The gas evolved was collected in a gas burette connected to the reflux condenser. After an irradiation, CO_2 and moisture-free air was blown through the system to flush all the gaseous reaction products into the burette. A VTI-2 gas analyzer and a Kh-1M chromathermographic gas analyzer of the Gor'kii Scientific Research Institute of Chemistry were used to determine the gas composition.

1. The photoreaction of mercuric acetate in benzene and in a mixture of benzene and acetic acid was continued until gas evolution ceased. After irradiation, the reaction mixture was cooled and filtered; the precipitate was washed with benzene. The mercurous and mercuric acetate contents of the precipitate were determined. The benzene solution was extracted with water, and treatment of the aqueous solution with KI gave a precipitate of methylmercuric iodide with m. p. 143-144° (from alcohol and ether); a mixed melting point with authentic methylmercuric iodide was not depressed. Metallic mercury was one of the reaction products in experiments in benzene with acetic acid added. No phenylmercuric compounds were found.

2. Photoreaction of mercuric acetate in acetic acid. The reaction mixture was cooled and the solution separated from metallic mercury and precipitate (when present). The precipitate was examined for mercurous and mercuric salt content. The acetic acid was removed from the acetic acid solution in vacuum. The residue was treated with benzene; in some experiments, this gave a precipitate which was likewise examined for mercurous and mercuric salt content. A precipitate of methylmercuric iodide was obtained from the benzene solution as above.

In experiments where irradiation was stopped when a considerable amount of the original salt still remained in the reaction mixture, gas evolution continued for a further 10-15 minutes (with the reaction mixture boiling).

3. Photoreaction of mercurous acetate in acetic acid. Metallic mercury was separated from the reaction mixture and washed with acetic acid and water. The acetic acid was removed from the acetic acid solution in vacuum; the precipitate was dissolved in water and treatment of it with KI gave methylmercuric acetate.

In experiment 11, the reaction mixture contained, in addition to mercury, a precipitate of unchanged salt. The precipitate was separated from the mercury by solution in dilute nitric acid; the mercurous salt was precipitated from the solution as mercurous chloride. The bulk of the solvent was removed from the acetic acid solution of the reaction mixture in vacuum. Cooling the residue gave a precipitate of mercurous acetate, which was removed by filtration. The filtrate was diluted with water and treatment with KI precipitated methylmercuric iodide; Hg^{++} ions were also found in the mother solution.

4. The photoreaction of mercuric propionate in benzene was continued until gas evolution ceased. The reaction mixture was filtered. The precipitate was mercurous propionate; it did not contain Hg^{++} ions. The benzene was removed from the benzene solution. The residue was dissolved in methanol; the solution was diluted with water and treatment with KI gave a precipitate of ethylmercuric iodide with m. p. 179-180° (after sublimation).

5. Photoreaction of mercuric propionate in propionic acid. Metallic mercury was separated from the reaction mixture. The solvent was removed from the propionic acid solution in vacuum. The residue was dissolved in water and treatment with KI gave a precipitate of ethylmercuric iodide with m. p. 179-180° (after sublimation).

In Experiment 17, irradiation was stopped after 45 minutes. The hot solution was separated from the precipitate of metallic mercury and cooled with water and snow. The precipitate was mercurous propionate; it did not contain Hg^{++} ions (tests with KI, KCl, and NH_4OH). Under the above treatment, the propionic acid solution yielded ethylmercuric iodide with m. p. 179-180° (after purification). Treatment of the mother solution with hydrogen sulfide yielded a precipitate of HgS.

SUMMARY

1. In a photoreaction in benzene, mercuric acetate and propionate form organometallic compounds of the type RHgOCOR and mercurous salts in 30-34 and 60-68% yields, respectively. The addition of acetic acid to the benzene promotes the photoreaction of mercuric acetate.

2. The compounds RHgOCOR and $Hg_2(OCOR)_2$ are stable to irradiation in benzene.

3. Photoreactions of mercurous and mercuric acetates in acetic acid and mercuric propionate in propionic acid give compounds of the type RHgOCOR and metallic mercury. The yields of organometallic compounds reach 66-68%.

4. A study of the composition of the gases evolved showed that in photoreactions of mercurous and mercuric acetates, the gas consists of CO_2, methane, ethane, and CO; in photoreactions of mercuric propionate the gas consists of CO_2, ethane, ethylene, butane, and CO.

5. Photoreactions of mercuric salts of aliphatic acids may be used as a convenient method for the synthesis of methylmercuric salts.

LITERATURE CITED

[1] G. A. Razuvaev and Yu. A. Ol'dekop, Doklady Akad. Nauk SSSR 105, 738 (1955).

[2] G. A. Razuvaev and Yu. A. Ol'dekop, Tr. po Khim. i Khim. Tekhnol. (Gor'kii) 1, 178 (1958).

[3] G. A. Razuvaev and Yu. A. Ol'dekop, Zhur. Obshchei Khim. 27, 196 (1957).*

[4] G. A. Razuvaev, Yu. A. Ol'dekop, and N. A. Maier, Doklady Akad. Nauk SSSR 98, 613 (1954).

[5] G. A. Razuvaev, Yu. A. Ol'dekop, and N. A. Maier, Zhur. Obshchei Khim. 25, 697 (1955).*

[6] Yu. A. Ol'dekop and N. A. Maier, Zhur. Obshchei Khim. 29, 299 (1959).*

[7] S. Goldschmidt, W. Leicher, and H. Haas, Lieb. Ann. 577, 153 (1952).

* Original Russian pagination. See C. B. translation.

PROPERTIES OF AMINO ACIDS AND PEPTIDES CONTAINING A TERTIARY NITROGEN ATOM

II. SYNTHESIS OF N,N-DIBENZYLPEPTIDES

N. A. Poddubnaya and Vyach. I. Maksimov

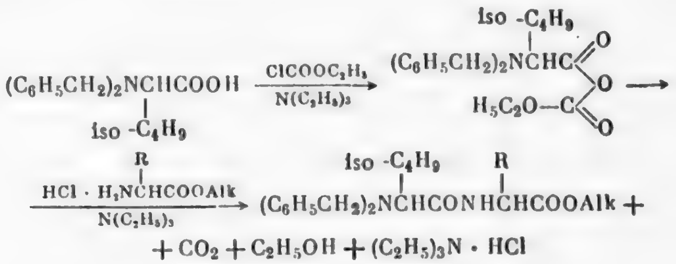
Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 308-312, January, 1960

Original article submitted August 4, 1958

In a previous report [1] we demonstrated the particular effect of two benzyl groups on the stability of the acid chlorides of N,N-dibenzyl-α-amino acids. It seemed interesting to study other phenomena connected with the presence of a tertiary nitrogen atom in a peptide molecule. This required the synthesis of a series of N,N-dibenzylpeptides with different amino acid compositions, which was done in the present work.

The N,N-dibenzylpeptides were prepared from mixed anhydrides and ethyl chlorocarbonate by the procedure of L. Velluz [2]. The synthesis was carried out by the scheme:



The mixed anhydride of N,N-dibenzylleucine was coupled with esters of amino acid or peptides in chloroform. This yielded compounds which were homogeneous chromatographically and electrophoretically. In paper electrophoresis in 30% acetic acid solution with a potential gradient of 6.6 v/cm, the substances moved the distances shown in Table 1. The electrophoregrams were developed with benzidine by the procedure in [3].

The synthesis of two compounds (N,N-dibenzylleucylphenylalanine and N,N-dibenzylleucylglycylglycine) convinced us of the ease of preparing N,N-dibenzylpeptides from their esters. In the preparation of the ethyl ester of N,N-dibenzylleucylphenylalanine by L. Velluz's method [2], we were unable to crystallize the product using the purification method proposed by the author. The substance could be obtained in a crystalline form only after hydrolysis to N,N-dibenzylleucylphenylalanine (m. p. 145°).

Due to the fact that N,N-dibenzylleucine dissolves readily in organic solvents while, with an increase in the number of peptide residues, its peptides dissolve less readily, N,N-dibenzylpeptides may be synthesized without isolation of their esters in a crystalline form and they may be freed from the starting materials readily, an operation which presents the greatest difficulty in the synthesis of peptides by the method of Boissonas [4].

N,N-Dibenzyldipeptides are readily separated from inorganic salts by washing with water as the former are water insoluble.

TABLE 1

Compound	Distance (in cm) (to cathode)		
	3 hours	4.5 hours	7 hours
N,N-Dibenzylleucine	1.2-1.5	2.8	3.5
Methyl ester of N,N-dibenzylleucylglycine	2.6	5.2	7.0
Methyl ester of N,N-dibenzylleucylalanine	2.6	5.0	6.2
Ethyl ester of N,N-dibenzylleucylphenylalanine	2.6	4.6	6.0
Ethyl ester of N,N-dibenzylleucylglycylglycine	3.2	–	–
Methyl ester of glycine	6.4	–	–
Ethyl ester of phenylalanine	4.8	–	–
Ethyl ester of glycylglycine	6.4	–	–

We demonstrated the readiness with which the dibenzyl blocking group is removed by the preparation of leucylphenylalanine. Hydrogenation of N,N-dibenzylleucylphenylalanine at 50-60° over Pd black in acetic acid gave a free dipeptide in 65% yield.

The constants and yields of the compounds prepared are given in Table 2.

TABLE 2

Substances prepared	Yield (in %)	Melting point
Methyl ester of N,N-dibenzylleucylglycine	80	80-82°
Methyl ester of N,N-dibenzylleucylalanine	84	102-105
Ethyl ester of N,N-dibenzylleucylphenylalanine	75	87-88
Ethyl ester of N,N-dibenzylleucylglycylglycine	64	115
Methyl ester of N,N-dibenzylleucylphenylalanylglycine	76	154
N,N-Dibenzylleucylphenylalanine	74	145
N,N-Dibenzylleucylglycylglycine	95 (from its ester	165

A biuret reaction with N,N-dibenzyltripeptides showed that these compounds form two types of copper complex: red and blue (λ_{max} 520 and 600 mμ, respectively).

The character of the light absorption of an N,N-dibenzyltripeptide depends on the presence of a terminal tertiary nitrogen atom in the peptide molecule and on the various amounts of alkali used in the biuret reaction. This observation will be the subject of our next investigation.

EXPERIMENTAL

Methyl ester of N,N-dibenzylleucylglycine. A sample of 1.55 g of N,N-dibenzylleucine and 0.69 ml of triethylamine were dissolved in 15 ml of anhydrous chloroform and cooled to −10°. Ethyl chlorocarbonate

(0.48 ml) was added and the solution kept at 0° for 30 minutes. A solution of 0.68 g of the hydrochloride of glycine methyl ester and 0.69 ml triethylamine in 30 ml of chloroform were added to the mixed anhydride solution. The mixture was shaken for 10-15 minutes at 0° and left overnight at room temperature. The chloroform was removed and the residual crystalline substance treated with dilute hydrochloric acid, washed with water, shaken with a 2 N sodium carbonate solution for 4-6 hours, and then washed again with water. The substance was dried in a Fischer pistol over acetone. The yield was 1.5 g (80%). M. p. 80-82°. For analysis, the substance was reprecipitated with water from acetone and dioxane.

Found %: C 71.89, 71.84; H 8.79, 8.72. $C_{23}H_{30}O_3N_2$. Calculated %: C 72.26; H 7.85.

The methyl ester of N,N-dibenzylleucylglycine was a white crystalline substance which dissolved in all organic solvents, including ligroin and cyclohexane. It was completely insoluble in water, hydrochloric acid, and aqueous solutions of alkali and sodium carbonate. Ninhydrin and biuret reactions were negative. The hydrolysis of the substance in 20% hydrochloric acid solution was investigated chromatographically with the system butanol – water – acetic acid (4 : 5 : 1) and two substances were found: glycine (R_f 0.07) and N,N-dibenzylleucine (R_f 0.95).

The methyl ester of N,N-dibenzylleucylalanine. The substance was prepared similarly to the previous one from 3.1 g of N,N-dibenzylleucine, 1.38 ml of triethylamine and 0.96 ml of ethyl chlorocarbonate in 30 ml of anhydrous chloroform. The mixed anhydride obtained was coupled with 2.1 g of the hydrochloride of alanine methyl ester in the presence of 2.07 ml of triethylamine in 125 ml of anhydrous chloroform. The substance was isolated and treated as in the first case. The material was freed from traces of N,N-dibenzylleucine by washing with 10-15 ml of ether. The yield was 3.5 g (85%); the m. p. was 102-105°.

Found %: C 69.72, 69.62; H 8.12, 8.16. $C_{24}H_{32}O_3N_2 \cdot H_2O$. Calculated %: C 69.54; H 8.27.

The dipeptide ester was a white, crystalline substance which was soluble in chloroform, ethyl acetate, benzene, and methanol; it was insoluble in water, hydrochloric acid, and solutions of alkali and sodium carbonate.

The ethyl ester of N,N-dibenzylleucylphenylalanine was prepared similarly to the previous compound from 1.55 g of N,N-dibenzylleucine, 0.69 ml of triethylamine and 0.96 ml of the ethyl chlorocarbonate in 15 ml of anhydrous chloroform. The mixed anhydride was mixed with a solution of 1.6 g of the hydrochloride of phenylalanine ethyl ester and 1.03 ml of triethylamine in 80 ml of chloroform. It was treated as in the previous case. The yield was 1.8 g (75%); m. p. 87-88°.

Found %: C 75.9, 75.9; H 7.81, 7.99; N 5.87, 6.01. $C_{31}H_{38}O_3N_2$. Calculated %: C 76.5; H 7.87; N 5.75.

The substance was soluble in all organic solvents and insoluble in water, hydrochloric acid, and aqueous solutions of alkali and sodium carbonate.

N,N-Dibenzylleucylphenylalanine. The dipeptide ester was synthesized as described above, but it was purified by washing the chloroform solution with dilute acid, water, sodium carbonate, and again with water; the chloroform solution was dried with sodium sulfate. Removal of the chloroform yielded an oil which could not be crystallized. An electrophoregram showed the presence of traces of N,N-dibenzylleucine. To remove the latter, the oil was dissolved in 50 ml of methanol, 2 N sodium hydroxide solution added until turbidity appeared, and the mixture left overnight. The solution was neutralized to about pH 6 with acetic acid, and water added gradually. The precipitate was collected by filtration and washed with water. The yield was 1.7 g (74%). To facilitate crystallization, the substance was kept over 30 ml of cyclohexane for 24 hours. The m. p. was 145°. The substance was readily soluble in chloroform and ethyl acetate and sparingly so in carbon tetrachloride, benzene, and cyclohexane.

Leucylphenylalanine. A sample of 0.2 g of N,N-dibenzylleucylphenylalanine in 5 ml of acetic acid was hydrogenated over 0.06 g of Pd black with hydrogen passed for 1.5 hours at 50-60°. The solution was then filtered and the acetic acid removed in vacuum. The oil that formed crystallized on addition of anhydrous alcohol. The precipitate was collected by filtration and washed several times with anhydrous alcohol. The yield was 0.7 g (65%); m. p. 218-220°. Literature data: m. p. 220-223° [5]. The substance gave a blue biuret reaction, which is characteristic of dipeptides (λ_{max} 620 mμ).

The ethyl ester of N,N-dibenzylleucylglycylglycine was prepared by the same procedure as for the methyl ester of N,N-dibenzylleucylglycine from 3.1 g of N,N-dibenzylleucine, 1.38 ml of triethylamine, and 0.96 ml of ethyl chlorocarbonate in 30 ml of anhydrous chloroform. The cool solution was mixed with 3.0 g of the hydrochloride of glycylglycine ethyl ester and 2.07 ml of triethylamine in 125 ml of chloroform. The chloroform solution was washed with dilute HCl, water, 2 N sodium carbonate solution, and again with water and dried with sodium sulfate. We isolated 3.2 g of substance. To free the product from N,N-dibenzylleucine, 15 ml of CCl_4 was added and the solution left for several days. The coarsely crystalline precipitate formed was collected by filtration and washed on the filter with 5 ml of carbon tetrachloride. The yield was 2.8 g (64%). The m. p. was 115°.

Found %: C 68.86, 68.61; H 7.92, 7.80. $C_{26}H_{35}O_4N_3$. Calculated %: C 68.87; H 7.73.

The substance was readily soluble in chloroform, ethyl acetate, benzene, methanol, and acetone, and less so in ethyl alcohol and carbon tetrachloride. It had R_f 0.95 in the system water – acetic acid – butanol (1:5:4). It gave differently colored complexes (λ_{max} from 510 to 600 mμ) with copper salts at different concentrations of alkali. A detailed investigation of the copper complexes of this substance will be described in the next communication.

N,N-Dibenzylleucylglycylglycine. A sample of 2.2 g of the tripeptide ethyl ester was dissolved in 50 ml of methanol. To the solution was added 30 ml of a 2 N sodium hydroxide solution (until slight turbidity appeared) and the mixture left overnight. The solution was neutralized with acetic acid and a large volume of water (up to 2 liters) added gradually. The precipitate was collected by filtration, washed with water, and dried. The yield was 1.9 g (95%). The m. p. was 164-165°.

Found %: N 9.66, 9.70. $C_{24}H_{31}O_4N_3$. Calculated %: N 9.88.

The substance was readily soluble in acetone, methanol, hot xylene, and hydrochloric acid; it was sparingly soluble in chloroform, carbon tetrachloride, and benzene; it was insoluble in water.

Methyl ester of N,N-dibenzylleucylphenylalanylglycine. A mixture of 0.5 g of N,N-dibenzylleucylphenylalanine and 0.28 ml of triethylamine in 15 ml of anhydrous chloroform was cooled to −10°, 0.1 ml of ethylchlorocarbonate added, the mixture kept at 0° for 30 minutes, and a solution of 0.2 g of the hydrochloride of glycine methyl ether and 0.2 ml of triethylamine in 30 ml of anhydrous chloroform added. The solution was kept at 0° for 30 minutes and at room temperature for 4 hours. Removal of the solvent gave crystals, which were washed with dilute hydrochloric acid and water. The substance was treated with 15 ml of ether. The yield was 0.42 g (76%). The m. p. was 154°.

Found %: C 72.44, 72.32; H 7.47, 7.42. $C_{32}H_{39}O_4N_3$. Calculated %: C 72.59; H 7.37.

The substance was readily soluble in chloroform and hot ethyl alcohol and less so in cold alcohol; it was insoluble in ether, water, and aqueous alkali.

SUMMARY

The following substances, which have not been described in the literature, were prepared by Boissonas' method: the methyl esters of N,N-dibenzylleucylglycine, N,N-dibenzylleucylalanine, and N,N-dibenzylleucylphenylalanylglycine, N,N-dibenzylleucylphenylalanine and its ethyl ester, and also N,N-dibenzylleucylglycylglycine and its ethyl ester.

LITERATURE CITED

[1] N. A. Poddubnaya and Vyach. I. Maksimov, Zhur. Obshchei Khim. 29, 3483 (1959).*

[2] L. Velluz, G. Anatol, and I. Amiard, Bull. Soc. Chim. (5), 21, 1449 (1954).

[3] E. Reindel and W. Hoppe, Ber. 87, 1103 (1954).

[4] R. A. Boissonas, Helv. Chim. Acta 34, 874 (1951).

[5] H. Leuchs and V. Suzuki, Ber. 37, 3306 (1904).

* Original Russian pagination. See C. B. translation.

PROPERTIES OF AMINO ACIDS AND PEPTIDES CONTAINING A TERTIARY NITROGEN ATOM

III. THE ABSORPTION SPECTRA OF DIBENZYLTRIPEPTIDE COPPER COMPLEXES

N. A. Poddubnaya and Vyach. I. Maksimov

Moscow State University

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 312-317, January, 1960

Original article submitted August 4, 1958

The biuret reaction of proteins and peptides, in which colored copper complexes are formed, is a qualitative reaction for a peptide bond. Extensive investigations have been carried out in this field [1-7] and the results have made it possible to formulate a new method for studying the structure of proteinaceous substances, their hydrolyzates at various stages of decomposition, and also synthetic peptides. It was established that blue complexes are characteristic of dipeptides, violet of tripeptides, and red of tetra- and pentapeptides, etc. The additional functional groups NH_2, OH, NH, $CONH_2$, etc. have a definite effect on color. N. I. Gavrilov, et al. developed a spectrophotometric method [1-3, 6] for studying the structures of copper complexes of proteins.

The complexes studied previously had approximately the same λ_{max} with different concentrations of alkali; therefore, the effect of the amount of alkali on the position of the absorption maximum was considered negligible.

In the present work, we studied the copper complexes of the ethyl ester of N,N-dibenzylleucylglycylglycine and were the first to note the change in the character of the light absorption over a wide range of wavelengths in relation to concentration of alkali.

The following facts were established.

1. With alkali concentrations of 0.125, 0.25, 0.5, 0.75, and 1.0 M in the presence of the same amount of copper (0.5 ml of 0.25 M copper acetate solution) and with the same concentration of the ethyl ester of N,N-dibenzylleucylglycylglycine (0.01 M/liter), copper complexes with different absorption maxima in the range 510-600 mμ were obtained. The λ_{max} value of 520 mμ corresponded to complexes with a lower alkali concentration and λ_{max} of 590 mμ corresponded to those with a higher concentration (Fig. 1).

According to the accepted classification [6] of copper complexes of peptides, in the first case we obtained an absorption spectrum which was closer to a tetrapeptide (λ_{max} 520 mμ), and in the second closer to a dipeptide (λ_{max} 620 mμ).

2. Despite different solvents (water, alcohol, and dioxane) the wavelengths of the different maxima remained approximately the same. Complexes with λ_{max} of 590-600 mμ formed more readily in alcohol than in water. As Fig. 2 (Curve 2) shows, with 0.4 g of alkali (1.0 M), the absorption intensity was considerably higher in 96% alcohol than in 50% alcohol (Fig. 1, Curve 5).

We consider that the change in absorption intensity with different states of the medium is due to the different stabilities of the copper complexes formed, as water promotes the dissociation of a complex. However, we consider that this question has not yet been settled conclusively.

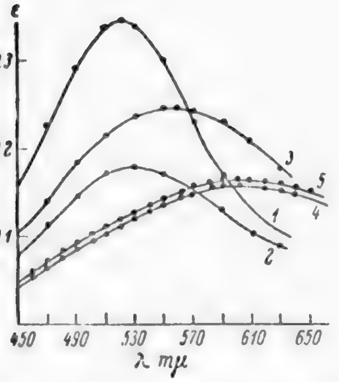


Fig. 1. Absorption spectra of copper complexes of the ethyl ester of N,N-dibenzylleucylglycylglycine in 50% alcohol. NaOH (in g): 1) 0.05; 2) 0.1; 3) 0.2; 4) 0.3; 5) 0.4.

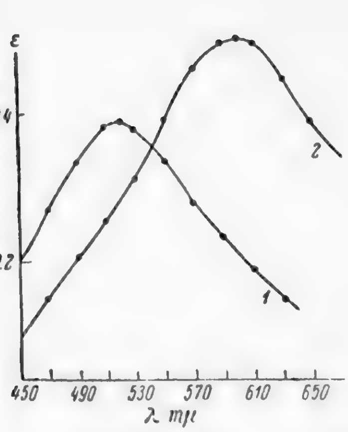


Fig. 2. Absorption spectra of copper complexes of the ethyl ester of N,N-dibenzylleucylglycylglycine in 96% alcohol. NaOH (in g): 1) 0.05; 2) 0.4.

3. The ester group did not have any appreciable effect on the position of λ_{max}, as the same positions of λ_{max} were obtained for N,N-dibenzylleucineglycylglycine (Fig. 3).

4. When acid was added to a solution of a complex with an absorption maximum at 590 mμ, we observed a displacement of the maximum toward shorter wavelengths (λ_{max} 520 mμ) and a simultaneous increase in the absorption intensity, characteristic of a given wavelength. Correspondingly, an increase in the alkali concentration of the same solution produced a reverse displacement of the absorption maximum to 590 mμ (Fig. 4).

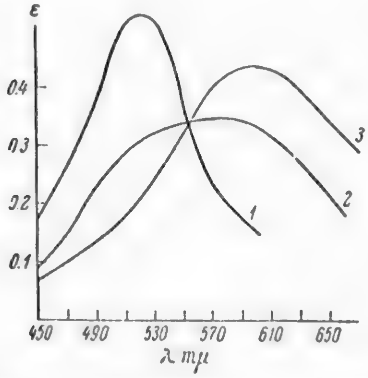


Fig. 3. Absorption spectra of copper complexes of N,N-dibenzylleucylglycylglycine in 96% alcohol. NaOH (in g): 1) 0.05; 2) 0.2; 3) 0.4.

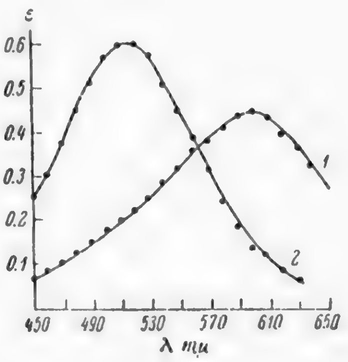
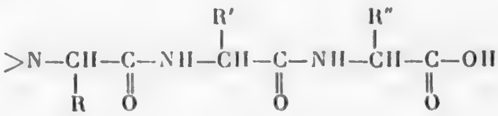


Fig. 4. Absorption spectra of copper complexes of N,N-dibenzylleucylglycylglycine ethyl ester in 50% alcohol. 1) Original dibenzyltripeptide ester, 0.4 g NaOH; 2) regenerated dibenzyltripeptide hydrochloride, 0.4 g NaOH.

These data give some grounds for assuming the formation of two types of complex which are in dynamic equilibrium and a displacement to one side or the other is observed with a change in the alkali concentration. The complex with an absorption maximum at 590 mμ is dissociated more strongly in an aqueous solution than in alcohol (see Figs. 1 and 2).

In the first approximation, the phenomenon of double complex formation may be explained by the effect of the dibenzyl blocking group on this process. Apparently, in this case, the dibenzyl blocking group acts in the same way as in the decomposition of the acid chloride [8], i.e., the increase in electron density at the tertiary nitrogen atom (increase in its basic properties) produces an increase in the basicity of the adjacent amide nitrogen atom by a mechanism which we are not as yet in a position to explain. Due to this, the presence of a tertiary nitrogen atom in dibenzyltripeptides results in unequal capacities of the two carbonyl groups to enolize, a phenomenon which is almost absent from a peptide with a free amino group. This is seen from an examination of a peptide formula.



A tripeptide molecule has two amide bonds. One bond is under the influence of the carboxyl,and the other under the influence of the terminal nitrogen atom. This differentiation is almost absent from a peptide with a free amino group, and actually appears in N,N-dibenzyltripeptides as a result of the different effect of the terminal amino and carboxyl groups. Thus, the absorption spectra of the copper complex of the free tripeptide leucylglycylglycine show a displacement of the absorption maximum of only 10 mμ (see table) at the two alkali concentrations (0.125 and 1.0 M). In the case of dibenzyltripeptides this difference reaches 90-100 mμ, depending on the alkali concentration (see Figs. 1-4).

At low alkali concentrations the carbonyl group of dibenzyltripeptides should be enolized very little and as a result, according to preliminary data, a copper complex forms in which there are two dibenzyltripeptide molecules per copper atom (λ_{max} 520 mμ). However, with an increase in alkali concentration, the enolization of the carbonyl group increases and this gives a monomolecular complex (λ_{max} 600 mμ).

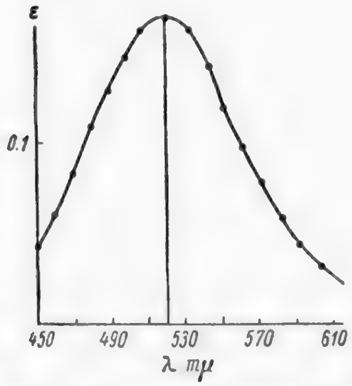


Fig. 5. Absorption spectrum of the copper complex of N,N-dibenzylleucylglycylglycine in excess triethylamine.

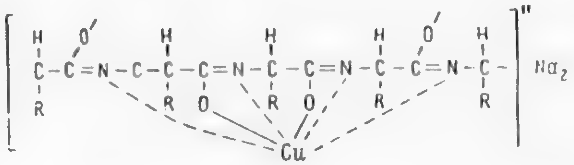
This is confirmed by the fact that we obtained only a red complex (λ_{max} 520 mμ, Fig. 5) for N,N-dibenzylleucylglycylglycine with triethylamine (without alkali). Triethylamine is too weak a base to displace the equilibrium toward a more enolized form. Triethylamine itself does not give a colored copper complex.

In addition, N,N-dibenzyldipeptides do not give colored copper complexes, which indicates that the terminal tertiary nitrogen atom in a peptide does not participate in complex formation. One dibenzyltripeptide, N,N-dibenzylglycylglycylglycine, is described in [9] and a dipeptide absorption maximum (620 mμ) is given for its copper complex [10]. However, the authors did not study the effect of alkali concentration on the complex-formation process; we plan to do so in the future.

We checked whether the double complex formation was induced by the dipeptide part of the molecule, i.e., whether this phenomenon was inherent in the dipeptide itself, by studying the complex formation of glycylglycine ethyl ester under the same conditions. In all cases, there was no displacement or very little (see table).

We were then able to establish that the character of light absorption of dibenzyltripeptides also depends on the amino acid composition, with the presence of phenylalanine in the peptide chain having a particular effect. Thus, at alkali concentrations of 0.125, 1.0, and 1.5 M, the methyl ester of N,N-dibenzylleucylphenylalanylglycine we prepared gave only a red complex with a 10 mμ displacement (510-520 mμ), but with a considerable fall in absorption intensity (see table). In the given case the hydrogen was replaced by benzyl in the glycine hydrocarbon chain,which resulted in an even greater concentration of electron density at the amide nitrogen; in this case, even high alkali concentrations did not induce the formation of a second complex.

We have not yet studied the problem of the structure of the complex and one reason for this is the fact that the generally accepted structure for a copper complex, proposed by M. Rising [11], M. I. Plekhan [12], K. T. Poroshin [7], J. Nilashi and Z. Kovats [13], does not provide an explanation for double complex



formation. Furthermore, a careful examination of this structure reveals that such copper complexes must be extremely unstable, due to the fact that copper has an uncharacteristic coordination number of 6 and that the principle put forward by L. Chugaev [14], according to which the 5- and 6-membered rings in a complex are the most stable ones, is not obeyed. In this case, the structure of the peptide copper complex must include two 4-membered rings, which must make the complex extremely unstable. This is contradictory to the facts, as peptide and protein copper complexes are extremely stable, and the copper evidently has its characteristic coordination number of 4.

It seems to us that the structure of copper complexes requires further proof, particularly if one considers the data we obtained on the effect of a terminal tertiary nitrogen atom on complex formation. Only a further study of this phenomenon will make it possible to solve conclusively the problem of the coordination number of copper, the disposition of the atoms in the inner sphere of the complex, the steric structure of the complex and the character of the enolization.

EXPERIMENTAL

Method of preparing copper complexes. The copper complexes of the peptides investigated were prepared by the method described previously [3]. In this work, we varied the amounts of alkali and used alcohol and water as solvents. The amount of copper acetate was 0.5 ml of a 0.25 M solution for each experiment. After the copper acetate had been added the solution was kept for one hour and then centrifuged. An SF-4 spectrophotometer was used for the spectrophotometric measurements. The data from the determination are summarized in the table.

1. Copper complex of glycylglycine ethyl ester. Mixtures of 0.0231 g of the hydrochloride of the dipeptide ethyl ester, 0.1 g and 0.45 g of NaOH,* and 0.5 ml of 0.25 M aqueous copper acetate solution were prepared in 10-ml graduated flasks. Water and 96% and 50% alcohol were used as solvents.

2. Copper complex of leucylglycylglycine. The amounts of the reagents were the same with a total volume of 10 ml; the tripeptide sample weighed 0.024 g and the solvent was 50% alcohol.

3. Copper complex of the ethyl ester of N,N-dibenzylleucylglycylglycine (Figs. 1 and 2). A 0.0453 g sample of tripeptide was used for a total volume of 10 ml; the amounts of alkali were 0.05, 0.1, 0.2, 0.3, and 0.4 g; the solvents were 50% and 95% alcohol.

4. Copper complex of N,N-dibenzylleucylglycylglycine (Fig. 3). The amounts of reagents were the same; a 0.0426 g sample of dibenzyltripeptide was used; the solvents were water + alcohol (8.5 : 1.5) and 50% and 96% alcohol.

5. Copper complex of the methyl ester of N,N-dibenzylleucylphenylalanylglycine. The amounts of reagents were the same as in the previous experiments; a 0.0529 g sample of N,N-dibenzyltripeptide was used; the solvent was 50% alcohol.

6. Interconversions of the copper complexes of the ethyl ester of dibenzylleucylglycylglycine (Fig. 4). When 20% HCl or a considerable amount of water was added gradually to the copper complex obtained in Expt. 3, the blue copper complex (λ_{max} 600 mμ) was converted into the red complex (λ_{max} 520 mμ).

* As the hydrochloride of the dipeptide ethyl ester was used, the amount of alkali in all experiments was increased by 0.05 g.

When concentrated alkali solution was added to the red complex obtained, there was an opposite displacement of λ_{max} toward longer wavelengths.

Position of Absorption Maxima of Copper Complexes in Different Media in Relation to the Alkali Concentration

Medium	Amt. of NaOH (in g)	Ethyl ester of glycylglycine		Leucylglycylglycine		Ethyl ester of N,N-dibenzylleucylglycylglycine		N,N-Dibenzylleucylglycylglycine		Methyl ester of N,N-dibenzylleucylphenylalanylglycine	
		λ_{max} (mμ)	ε_{max}	λ_{max} (mμ)	ε_{max}	λ_{max} (mμ)	ε_{max}	λ_{max} (mμ)	ε_{max}	λ_{max} (mμ)	ε_{max}
Water	0.05	620	0.760	—	—	—	—	—	—	—	—
	0.4	620	0.720	—	—	—	—	—	—	—	—
50% Alcohol	0.05	610	0.685	560	0.830	520	0.350	520	0.340	510	0.350
	0.1	—	—	—	—	530	0.190	520	0.180	—	—
	0.2	—	—	—	—	560	0.230	550	0.220	—	—
	0.3	—	—	—	—	—	—	580	0.180	520	0.125
	0.4	610	0.670	570	0.845	610	0.150	590	0.150	520 *	0.120
96% Alcohol	0.05	610	0.700	—	—	520	0.350	520	0.500	—	—
	0.1	—	—	—	—	580	0.365	—	—	—	—
	0.2	—	—	—	—	590	0.470	580	0.325	—	—
	0.3	—	—	—	—	590	0.460	—	—	—	—
	0.4	610	0.670	—	—	600	0.490	600	0.400	—	—

* 0.6 g of NaOH.

SUMMARY

1. The peculiar character of the complex formation of N,N-dibenzyltripeptides with copper ions in an alkaline medium was studied.

2. It was established that N,N-dibenzylleucylglycylglycine gave two complexes with λ_{max} at 520 and 600 mμ at alkali concentrations of 0.125 and 1.0 M, respectively.

3. It was shown that the introduction of a phenylalanine amino acid residue into a peptide chain displaced the absorption maximum toward shorter wavelengths.

4. It was shown that the two types of copper complexes are capable of interconversions, depending on the hydrogen ion concentration.

A preliminary explanation is given for this phenomenon.

LITERATURE CITED

[1] N. I. Gavrilov and E. I. Ginzburg, Arkhiv. Biol. Nauk 39, 87 (1937).

[2] N. I. Gavrilov, A. I. Govorov, and A. I. Paradashvili, Biokhimiya 4, 45 (1939).

[3] N. I. Gavrilov, M. I. Plekhan, and N. A. Poddubnaya, Izvest. Akad. Nauk SSSR, Otdel Khim. Nauk 1, 127 (1941).

[4] N. A. Poddubnaya and N. I. Gavrilov, Zhur. Obshchei Khim. 18, 648 (1948).

[5] N. A. Poddubnaya and N. I. Gavrilov, Zhur. Obshchei Khim. 18, 662 (1948).

[6] M. I. Plekhan and N. I. Gavrilov, Zhur. Obshchei Khim. 21, 312, 316, 574 (1951). *

[7] K. T. Poroshin, Izvest. Akad. Nauk SSSR, Otdel Khim. Nauk 1952, 972.*

* Original Russian pagination. See C. B. translation.

[8] N. A. Poddubnaya and V. I. Maksimov, Zhur. Obshchei Khim. 29, 3483 (1959).*

[9] L. Velluz, J. Amiard, and R. Heymes, Bull. Soc. Chim. 21, 1012 (1954).

[10] N. I. Gavrilov, L. N. Akimova, and A. A. Akimova, Zhur. Obshchei Khim. 27, 2268 (1957).*

[11] M. Rising, F. Parker, and D. Jaston, J. Am. Chem. Soc. 56, 1178 (1934).

[12] M. I. Plekhan, Zhur. Obshchei Khim. 22, 1633 (1952).*

[13] J. Nilashi and Z. Kovats, Acta Chim. Acad. Scien. Hung. 4, 11 (1954).

[14] L. Chugaev, Zhur. Russ. Khim. Obshch. 7, 38 (1909); Ber. 40, 1973 (1907).

* Original Russian pagination. See C. B. translation.

TERNARY SYSTEM OF UREA AND SODIUM AND POTASSIUM ACETATES

A. K. Nesterova and A. G. Bergman

Stalingrad Pedagogical Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 317-320, January, 1960

Original article submitted December 10, 1958

A study of the reactions of urea with different salts in aqueous solutions and in melts is of considerable interest from the point of view of preparing combined fertilizers which contain urea (46.6% nitrogen) as the nitrogen-containing substance and salts of such elements as Cu, Zn, Co, Mg, etc. as the trace elements [1-3], and also for preparing low-melting urea-based melts. Molten urea dissolves various salts quite readily and as a result, its melting point falls very considerably. The reaction of urea with salts in melts has not been studied sufficiently [4]. In the present work we present the results of studying the reaction of urea with sodium and potassium acetates in a melt.

EXPERIMENTAL

The melting points were investigated by the visual polythermal method with the aid of glass tubes in a glycerol bath; the temperature was measured with a thermometer with an accuracy of ±0.5°. Chemically pure, recrystallized reagents were used in the work. The compositions are given everywhere in mole percents.

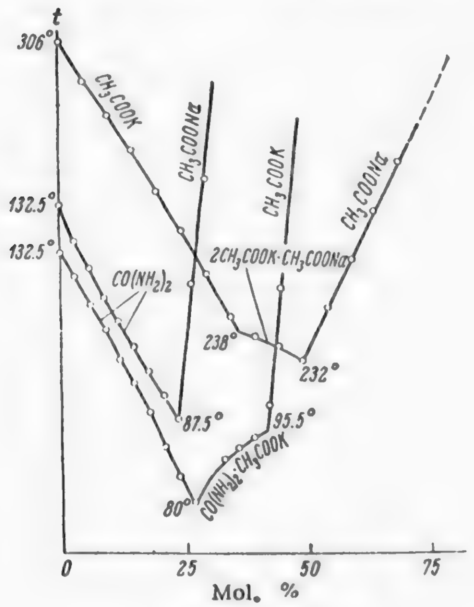


Fig. 1. Side binary systems.

Binary Systems

1. The $CO(NH_2)_2 - CH_3COONa$ system (Fig. 1, table). We were the first to study this system. It is a simple system with a eutectic at 87.5° and 24% CH_3COONa.

2. The $CO(NH_2)_2 - CH_3COOK$ system (Fig. 1, table). This was studied for the first time. One compound was formed with the composition $CO(NH_2)_2 \cdot CH_3COOK$ and this melted with decomposition. The transition point corresponded to 95.5° and 42% CH_3COOK, the eutectic point was at 80° and 27% CH_3COOK.

3. The $CH_3COOK - CH_3COONa$ system (Fig. 1, table) [4, 5]. We repeated previous investigations. The compound $2CH_3COOK \cdot CH_3COONa$ formed and this melted with decomposition. According to our data the eutectic corresponded to 232° and 50% CH_3COONa; the transition point was at 238° and 36.5% CH_3COONa.

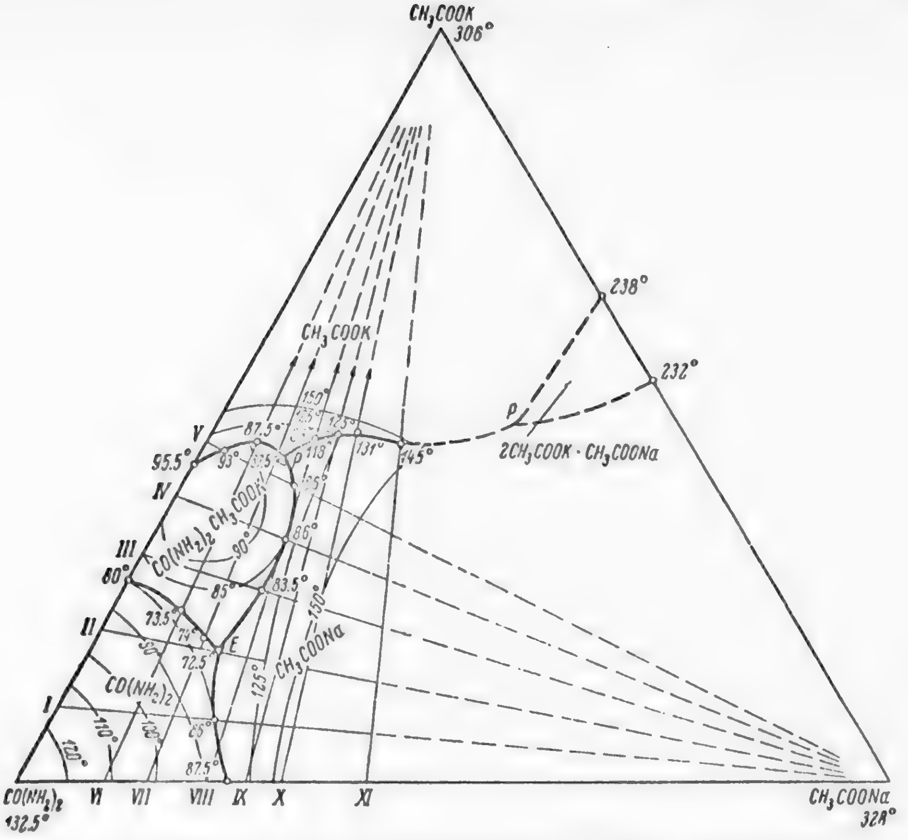


Fig. 2. Melting point diagram of the ternary system $CO(NH_2)_2-CH_3COONa-$ $-CH_3COOK$.

Fig. 3. Projection of cocrystallization curves onto the $CH_3COOK-CO(NH_2)_2$ side.

Binary Systems

$CO(NH_2)_2-CH_3COOK$ system				$CH_3COOK-CH_3COONa$ system				$CO(NH_2)_2-CH_3COONa$ system	
CH_3COOK (mol.%)	m. p.	CH_3COOK (mol.%)	m. p.	CH_3COONa (mol.%)	m. p.	CH_3COONa (mol.%)	m. p.	CH_3COONa (mol.%)	m. p.
0	132.5°	24	86°	0	306°	40	237°	0	132.5°
3	127.5	27	80.5	5	290	45	235	3	125
6	121.5	33	89.5	10	283	50	232	6	119.5
9	116.5	36	92.0	15	276	55	243	9	113.5
12	110.5	39	94.0	20	267	60	253	15	108.5
15	105.5	42	100.5	25	259	65	263	18	103
18	99	45	125	30	250	70	273	21	98
21	92	48	150	35	241			24	88
								27	116
								30	138

Ternary System Diagram

Eleven internal cross sections were studied (their directions are shown in Fig. 2) and from the results obtained we plotted the crystallization surface of the system. It consists of five fields, two of which belong to side complex compounds and three, to the system's components. A projection of the cocrystallization curves (Fig. 3) made it possible to define more accurately the composition and character of the invariant points.

The system has three ternary points: a eutectic point E [72.5°, 17% CH_3COOK, 15% CH_3COONa, 68% $CO(NH_2)_2$], a transition point P[88°, 43% CH_3COOK, 9% CH_3COONa, 48% $CO(NH_2)_2$] and a ternary transition point R, at which the field of the side complex $2CH_3COOK \cdot CH_3COONa$ tails away to nothing; the composition corresponding to this point is only approximate as it was impossible to study this region directly due to the vigorous decomposition of urea above 150°. The compound $CO(NH_2)_2 \cdot CH_3COOK$, which is incongruent at the side, has the tendency to become more stable, and becomes congruent within the system, as the direction of the cocrystallization curve of $CO(NH_2)_2 \cdot CH_3COOK + CH_3COOK$ indicates. A section drawn from the point of this compound to the CH_3COONa apex cuts the system into two phase triangles: the triangle $CO(NH_2)_2 - CH_3COONa - CO(NH_2)_2 \cdot CH_3COOK$ with point E and the triangle $CO(NH_2)_2 \cdot CH_3COOK - CH_3COONa - CH_3COOK$ with point P. As point R is a wedge point, it is not included in the triangulation of the system.

We should note the considerable viscosity of the melts in the region of the ternary eutectic point E.

SUMMARY

1. The reaction of urea with sodium and potassium acetates was studied. An incongruent complex compound of urea and potassium acetate, $CO(NH_2)_2 \cdot CH_3COOK$, forms and this melts at 95.5° with decomposition. The presence of sodium acetate in the ternary system helps to stabilize this compound.

2. The crystallization surface of the ternary system $CO(NH_2)_2 - CH_3COONa - CH_3COOK$ consists of five fields, two of which belong to side complexes and three to the system's components.

3. The system contains three ternary invariant points: a eutectic point E (72.5°), a transition point P (88°), and a transition point R, at which the field of the compound $2CH_3COOK \cdot CH_3COONa$ tails away to nothing.

LITERATURE CITED

[1] A. G. Bergman and K. Sulaimankulov, Zhur. Neorg. Khim. 2, 2813 (1957).

[2] K. Sulaimankulov and A. G. Bergman, Zhur. Neorg. Khim. 2, 2226 (1957).

[3] K. Sulaimankulov, I. G. Druzhinin, and A. G. Bergman, Zhur. Neorg. Khim. 2, 2668 (1957).

[4] A. G. Bergman and K. A. Evdokimova, ISFKhA Akad. Nauk SSSR 27, 296 (1956).

[5] N. N. Sokolov and E. I. Pochtakova, Zhur. Obshchei Khim. 28, 1397 (1958).*

* Original Russian pagination. See C. B. translation.

CATALYTIC DEHYDROGENATION OF 2-ETHYLTHIOPHENE

A. A. Balandin, G. M. Marukyan, R. G. Seimovich,
T. K. Lavrovskaya, and I. I. Levitskii

N. D. Zelinskii Institute of Organic Chemistry

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 321-324, January, 1960
Original article submitted December 22, 1958

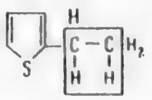
Vinylthiophene and its homologues are easily polymerizable compounds which can be used for copolymerization, e.g., with styrene and o-chlorostyrene.

It is known [1] that the ease of polymerization of monomers decreases in the following order: α-vinylthiophene > vinylpyridine > o-chlorostyrene > styrene. The use of 2-vinylthiophene for copolymerization with butadiene has been discussed in [2]. Polymers of vinyl derivatives of the thiophene series possess high softening temperatures and excellent dielectric properties [3].

Some synthetic methods for the preparation of vinylthiophene are known from the literature. Strassburg and his co-authors [4] made α-vinylthiophene from bromothiophene and vinylchloride with yields of up to 28.7%. Kuhn and Dann [5] synthesized 2-vinylthiophene by the reduction of 2-acetothienone to the carbinol and dehydration of the latter. Emerson and Patrick [6] prepared 2-vinylthiophene from thiophene and paraldehyde. From [3, 7] it is possible to make 2-vinylthiophene by condensing thienylmagnesium iodide with ethylene oxide and dehydrating the carbinal obtained with powdered potassium hydroxide: In this case the yield reached 50%. F. Ya. Perveev and N. I. Kudryashova [8] demonstrated the possibility of making vinyl and alkylthiophenes by the interaction of oxides of the acetylene and vinylacetylene series with hydrogen sulfide in the presence of barium hydroxide.

In our laboratories, we have for a long time carried out work on the catalytic dehydrogenation of alkyl-aromatic compounds; in this way, we have obtained various monomers, many of which acquired practical value [9-12]. We became interested in extending the exploitation of our methods to the dehydration of compounds containing heterocycles.

In the present report are described the results of an investigation into the dehydrogenation of 2-ethylthiophene with the formation of 2-vinylthiophene. According to the multiplet theory [14, 15] dehydrogenation of the ethyl group takes place by the doublet mechanism; the catalytic dehydrogenation of ethylthiophene may be represented by the scheme:



where the reacting atoms, which come into contact with the active center of the catalyst, are surrounded by the box.

It could be expected that the conditions for dehydrogenating ethylthiophene would be little different from those for the dehydrogenation of the monoalkylbenzenes. Indeed, the preparation of 2-vinylthiophene from ethylthiophene by passing the latter at high temperature over chromium oxide supported on bauxite has been described in a patent [13].

Before proceeding to investigate the dehydrogenation of ethylthiophene to vinylthiophene in the presence of the diluent water vapor, it is necessary to find out if the sulfur in the ethylthiophene molecule changes into oxygen by the Yu. K. Yur'ev reaction [16]. Other complicated reactions could be the breaking-off of the side group of ethylthiophene. A. A. Balandin, L. I. Sovalova, and T. A. Slovokhotova [17] observed a similar reaction, namely the demethylation of methylthiophene with the preservation of the thiophene ring under the influence of water gas with various catalysts (nickel or cobalt on aluminum oxide).

Our investigations showed that the formation of 2-vinylthiophene on dehydrogenation of 2-ethylthiophene goes smoothly enough with a yield of about 60%. The thiophene ring in these conditions appeared to be stable and removal of the side group proceeds to a negligible degree.

EXPERIMENTAL

The initial 2-ethylthiophene* had the following constants: b. p. 135.0-135.5° (741.5 mm), $n^{20}D$ 1.5130, d^{20}_4 0.990. Literature data [18]: b. p. 134-135°, $n^{20}D$ 1.5122, d^{20}_4 0.9904.

The dehydrogenation of 2-ethylthiophene was carried in a flow system at atmospheric pressure either without dilution or diluted with carbon dioxide or water vapor. The reaction was investigated at 500-600° and a volume rate of 0.15-0.38 $hour^{-1}$ in the presence of certain catalysts made from copper and lead oxides in various proportions and from copper and chromium oxides. The activity of the catalysts was controlled by experiments with ethylbenzene. The catalyzates were collected in a receiver provided with a condenser, and the products were removed to a graduated gasometer and then analyzed in an Ors apparatus. The possibility of using the Rosenmund [13] bromometric titration for the analysis of the ethylthiophene catalyzate was examined. The determinations showed that, when thiophene and ethylthiophene were brominated, two atoms of bromine were used up (per molecule of starting material). Therefore, the corresponding correction for bromination of the thiophene ring was applied when the catalyzate was brominated.

The results of experiments on the dehydrogenation of 2-ethylthiophene on a copper-chromium catalyst are cited in Table 1.

TABLE 1

Dehydrogenation on a Copper-Chromium Catalyst

Temp.	Duration of expt. (in min)	Rate of feed (hr^{-1})	Diluent	Catalyzate yield (wt. %)	n^{20}_D of catalyzate	Amt. of unsaturation in catalyzate (%)
600*	90	0.32	CO_2	87.7	—	48.9
500	60	0.22	—	90.0	1.5164	36.5
525	60	0.34	—	95.5	1.5210	39.1
550	45	0.20	—	83.3	1.5266	40.1
600*	60	0.30	CO_2	—	—	41.9

* These experiments were carried out with ethylbenzene.

* The 2-ethylthiophene was presented to us by Ya. L. Gol'dfarb to whom we extend our thanks.

The exit gases in the experiments with ethylthiophene did not contain hydrogen sulfide but consisted of hydrogen and a very small amount (up to 0.2%) of unsaturated hydrocarbons. From the data cited, it follows that the dehydrogenation of ethylthiophene occurs to the extent of 36-40% at 500-550°.

In order to find out the behavior of thiophene in our experimental conditions we passed thiophene, diluted with water vapor (1 : 2), over a catalyst composed of iron and copper oxides at 570° at a rate of 0.25 hour^{-1}. The analysis of the condensate obtained was:

Found %: C 57.93, 57.72; H 4.96, 4.96; S 37.6, 36.9. C_4H_4S. Calculated %: C 57.2; H 4.7; S 38.1.

Thus, thiophene passes through the catalyst practically unchanged under our conditions.

Dehydrogenation of 2-ethylthiophene diluted with water vapor was carried out in the presence of a catalyst composed of iron and copper oxides. The results of these experiments are cited in Table 2.*

TABLE 2

Dehydrogenation of 2-Ethylthiophene on a Mixed Oxide Catalyst in the Presence of a Diluent. Volume of Catalyst 25 ml.

Experimental temperature	Duration of experiment	Rate of feed of ethylthiophene (hour^{-1})	Ratio (w/w)		Yield of catalyzate (wt. %)	Unsaturation of catalyzate (wt. %)	Gas resulting from experiment (liters)	Analysis of gas*			
			ethylthiophene : H_2O	ethylthiophene : CO_2				CO_2 + H_2S	C_nH_m	O_2	H_2
600—610°**	2 hr 30'	0.24	1 : 2	—	97	54.0	—	—	—	—	—
600—607	1 hr	0.24	1 : 2	—	80	56.5	1.73	12.8	1.0	0.2	76.8
550—553	1 hr	0.24	1 : 2	—	92.5	50.4	0.6	8.2	0.4	1.4	—
525—530	1 hr 30'	0.22	1 : 2.2	—	90.1	56.7	0.625	—	0.2	0.0	80.0
575—578	1 hr 30'	0.24	1 : 1.7	—	84.0	60.3	1.225	6.4	0.6	0.2	78.5
596—601	1 hr 30'	0.24	1 : 2	—	82.7	51.4	1.5	8.8	0.8	0.0	77.4
597—600 **	3 hr	0.23	1 : 1.9	—	91.8	43.0	—	—	—	—	—
602—605	1 hr 30'	0.24	—	—	80.0	51	1.35	7.4	2.8	0.2	64.3
575 ***	2 hr 15'	0.23	—	1 : 2	83.2	52.5	1.344	0.4	2.6	0.2	55.4
550	2 hr	0.21	—	1 : 2	90.0	54.7	—	—	—	—	—
550 ***	2 hr 30'	0.22	—	1 : 2	—	51.6	0.39	0.0	1.6	0.4	—
600—607 **	3 hr	0.20	1 : 2.9	—	97.3	41.0	—	—	—	—	—
588—590	1 hr 45'	0.38	1 : 1.8	—	87.1	43.8	1.53	0.0	1.0	0.2	95.1
593—596	1 hr	0.15	1 : 3.4	—	91.7	47.2	1.56	13.6	0.8	0.4	81.0
589—599 **	1 hr	0.19	1 : 1.7	—	82.0	44.0	—	—	—	—	—
568	1 hr	0.31	1 : 2	—	—	47.9	0.37	—	—	—	—

* The maximum hydrocarbons in the gas were not determined.

** Carried out with ethylbenzene.

*** Carbon dioxide in the gas analyzed was absorbed with alkali.

From an examination of the data in Table 2, it follows that at 525-575° the dehydrogenation of ethylthiophene is complicated very little by decomposition side reactions. The negligible quantity of unsaturated hydrocarbons in the exit gases (0.2-0.8%) and the high yield of catalyzate (90% and higher) both indicate this. The amount of ethylthiophene dehydrogenation in these experiments was better than 50%. The dilution of ethylthiophene with carbon dioxide in the presence of the same catalyst led to somewhat worse results: The decomposition reaction was more intense, the content of unsaturated hydrocarbons in the exit gas increased from 1.6 to 2.8%; however, the content of unsaturates in the catalyzate also exceeded 50%.

* The last four experiments were carried out with another sample of catalyst prepared from copper and iron nitrates.

SUMMARY

An investigation of the catalytic dehydrogenation of 2-ethylthiophene into 2-vinylthiophene at 500-600° in the presence of oxide catalysts with various compositions, both with dilution of the ethylthiophene with carbon dioxide or water vapor and without dilution, was carried out. The best results were obtained with a copper-iron catalyst; the content of vinylthiophene in the catalyzate reached 50-60%.

LITERATURE CITED

[1] C. Walling, J. Am. Chem. Soc. 70, 1543 (1948).

[2] Synthetic Rubber (New York, 1954), 694.

[3] I. V. Andreev and M. M. Koton, Doklady Akad. Nauk SSSR 110, 75 (1956).*

[4] R. N. Strassburg, R. A. Gregg, and Ch. Walling, J. Am. Chem. Soc. 69, 2141 (1947).

[5] Kuhn and Dann, Lieb. Ann. 547, 293 (1941).

[6] W. S. Emerson and T. M. Patrick, J. Org. Chem. 13, 729 (1948).

[7] I. V. Andreev and M. M. Koton, Zhur. Obshchei Khim. 27, 997 (1957).*

[8] F. Ya. Perveev and N. I. Kudryashova, Zhur. Obshchei Khim. 23, 976 (1953).*

[9] A. A. Balandin and G. M. Marukyan, Zhur. Priklad. Khim. 19, 1277 (1946).

[10] A. A. Balandin and G. M. Marukyan, Zhur. Priklad. Khim. 19, 208 (1946).

[11] A. A. Balandin, G. M. Marukyan, and P. G. Seimovich, Doklady Akad. Nauk SSSR 41, 71 (1943).

[12] A. A. Balandin and G. M. Marukyan, Doklady Akad. Nauk SSSR 55, 127 (1947).

[13] U. S. Patent 2,689,855 (1954); Chem. Abstr. 49, 11720 (1955).

[14] A. A. Balandin, Zhur. Russk. Khim. Obshch. 59, 909 (1929).

[15] A. A. Balandin, Uspekhi Khim. 4, 1004 (1935).

[16] Yn. K. Yur'ev, Uch. Zap. Moscow State University, Vyp. 79, Org. Khim. (1945).

[17] A. A. Balandin, L. I. Sovalova, and T. A. Slobokhotova, Doklady Akad. Nauk 120, 775 (1958).

[18] Hartough Howard, Thiophene and Its Derivatives (London, 1952), p. 62.

[19] K. Rosenmund and W. Kuhnhenn, Z. f. Untersuch. d. Nahrungs und Genussmittel 46, 154 (1923).

* Original Russian pagination. See C. B. translation.

p-DI-(2-CHLOROETHYL)-AMINOPHENYLALANINE ("SARCOLYSINE") AND ITS DERIVATIVES

V. HETEROCYCLIC AMIDES OF SARCOLYSINE

A. Ya. Berlin and V. P. Bronovitskaya

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 324-327, January, 1960

Original article submitted November 3, 1958

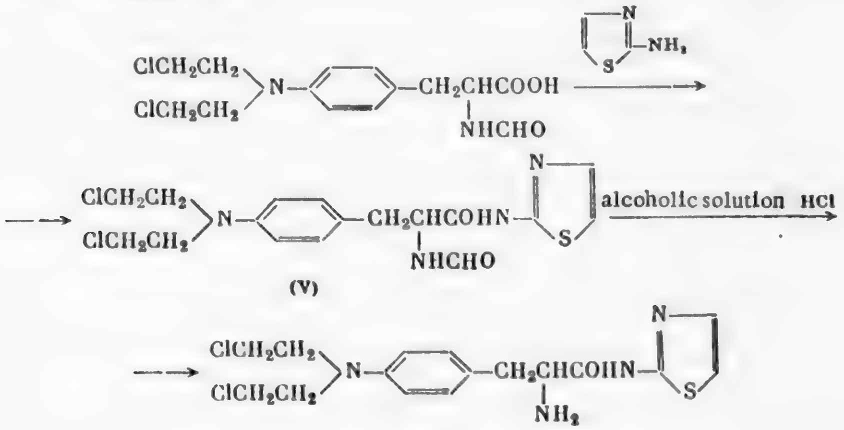
Examination of the carcinolytic properties of peptides of p-di-(2-chloroethyl)-aminophenylalanine ("sarcolysine") showed that some of these possessed antitumor properties similar to sarcolysine and, at the same time, a lower toxicity [1].

On considering the structural features of these peptides we became interested in synthesizing compounds in which the sarcolysine or α-N-acylsarcolysine residue was joined by an amide bond to different heterocyclic amines which were widely used in pharmaceutical chemistry.

Thus, by condensing N-acetyl- [2] and N-formyl-sarcolysine [3] with some heterocyclic amines in the presence of 1,3-dicyclohexylcarbodiimide by Sheeham's method [4], we obtained the (thiazolyl-2)-amide (I), (4 methylthiazolyl-2)-amide (II), piperidide (III), and morpholide of N-acetylsarcolysine (IV) and the (thiazolyl-2)-amide of N-formylsarcolysine (V).

However, in all these compounds the α-amino groupin the sarcolysine is acylated,whereas Bergel and Stock [5] hold the opinion that the presence of free amino group is important for the development of of antitumor activity.

In order to examine this the (thiazolyl-2)-amide of N-formylsarcolysine, which was synthesized from N-formylsarcolysine and 2-aminothiazole, was hydrolyzed with hydrochloric acid in the cold [6] to give the (thiazolyl-2)-amide of sarcolysine (VI).

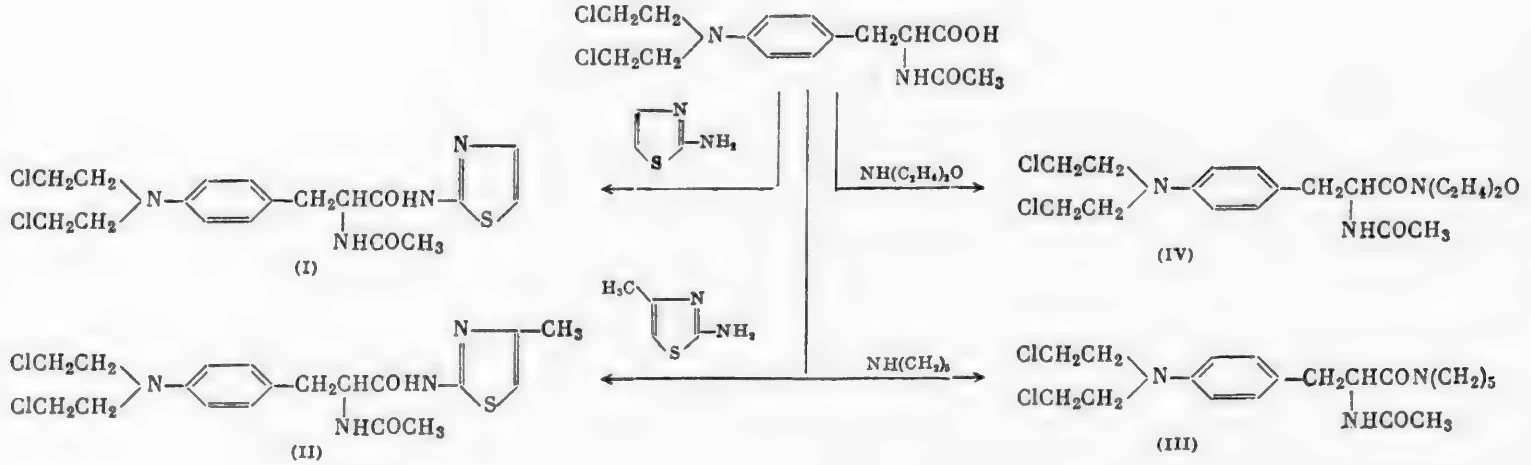


(V)

(VI)

Heterocyclic Amides of Sarcolysine

Compound	Empirical formula	Yield (%)	M. p.	Found (%)				Calculated (%)			
				C	H	N	Cl	C	H	N	Cl
(Thiazolyl-2)-amide of N-acetylsarcolysin (I)	$C_{18}H_{22}O_2N_4Cl_2S$	52.2	165.5–166.5°	50.35	5.04	12.62	16.53	50.35	5.13	13.05	16.55
(4-Methylthiazolyl-2)-amide of N-acetylsarcolysin (II)	$C_{19}H_{24}O_2N_4Cl_2S$	62.2	183–184	51.42	5.52	12.29	16.04	51.46	5.41	12.60	16.00
Piperidide of N-acetyl-sarcolysin (III)	$C_{20}H_{29}O_2N_3Cl_2$	57.4	148–149	57.95	7.02	10.45	16.89	57.97	7.00	10.14	17.15
Morpholide of N-acetyl-sarcolysin (IV)	$C_{19}H_{27}O_3N_3Cl_2$	65.2	155–156	54.28	6.66	10.17	17.11	54.80	6.49	10.09	17.08
(Thiazolyl-2)amide of N-formylsarcolysin (V)	$C_{17}H_{20}O_2N_4Cl_2S$	80.5	170–171	49.15	4.81	12.93	16.86	49.15	4.82	13.49	17.10



Results of the biological investigation will be published elsewhere.

EXPERIMENTAL

General Method of Obtaining Heterocyclic Amides of Sarcolysine

Equimolecular quantities of 1,3-dicyclohexylcarbodiimide and the requisite heterocyclic amine in chloroform were added successively to a suspension of 0.01 moles of N-acylsarcolysine in chloroform. The mixture was shaken and left at room temperature for 5 hours [25-30 minutes in the preparation of the (thiazolyl-2)-amide of N-formylsarcolysine (V)], after which the precipitated 1,3-dicyclohexylurea was filtered off, and the filtrate left at room temperature overnight. The precipitated amide was filtered off or, if the amide appeared to be very soluble, the chloroform solution was evaporated in vacuum, absolute alcohol was added to the residue and the product left in a refrigerator to crystallize. The crystalline amide which separated was recrystallized from absolute alcohol (see table).

The (thiazolyl-2)-amide of sarcolysine. 2.2 g of the (thiazolyl-2)-amide of N-formylsarcolysine (V) was dissolved in 300 ml of a 1-normal solution of hydrochloric acid in absolute alcohol, and the solution was stood for 1 hour at room temperature after which it was concentrated in vacuum to a small volume. The resulting precipitate was filtered off and recrystallized from absolute alcohol. The yield of (thiazolyl-2)-amide of sarcolysine hydrochloride was 1.5 g (68%). M. p. 226-227° (in a capillary immersed in the apparatus at 210°).

SUMMARY

1. The (thiazolyl-2)-amide, (4-methylthiazolyl-2)-amide, piperidide,and morpholide of N-acetylsarcolysine and the (thiazolyl-2)-amide of N-formylsarcolysine have been synthesized by condensing N-acetyl- or N-formyl-sarcolysine with certain heterocyclic amines.

2. The (thiazolyl-2)-amide of sarcolysine has been obtained by the hydrolysis of the (thiazolyl-2)-amide of N-formylsarcolysine.

LITERATURE CITED

[1] L. F. Larionov and Z. P. Sof'ina, Doklady Akad. Nauk SSSR 114, 1070 (1957).*

[2] N. A. Vodolazskaya, M. A. Novikova, E. N. Shkodinskaya, O. S. Vasina, A. Ya. Berlin, and L. F. Larionov, Byull. Éksper. Biol. Med. 1957, No. 11, 76.*

[3] I. L. Knunyants, O. V. Kil'disheva, and N. E. Golubeva, Investia Akad. Nauk SSSR, Otdel. Khim. Nauk 1956, 1418.*

[4] C. Sheehan and G. Hess, J. Am. Chem. Soc. 77, 1067 (1955).

[5] F. Bergel and J. A. Stock, J. Chem. Soc. 1957, 4563; Pr. Roy. Soc. 1957, 60.

[6] S. Waley, Chem. and Ind. 1953, 107.

* Original Russian pagination. See C. B. translation.

PREPARATION OF DERIVATIVES OF 6-AMINO-7-METHYLPURINE AS POSSIBLE ANTIMETABOLITES

G. Ya. Uretskaya, E. I. Rybkina, and G. P. Men'shikov

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 327-332, January, 1960

Original article submitted December 17, 1958

In recent years research on antitumor substances has led to certain widely known principles, according to which definite substances can act as antimetabolites of the nuclear functions of malignant cells.

It is known that some compounds of the purine series, e.g., adenine, guanine, etc., which may be considered as antimetabolites, cause shorter or longer remissions in the treatment of malignant neoplasms. Thus 6-mercaptopurine, 6-thioguanidine, and 6-chloropurine are used in the treatment of acute leucosis.

The aim of our work was the preparation of similar antitumor substances among the amino derivatives of 7-methylpurine. 2,6-Dichloro-7-methylpurine was used as the starting material for the synthesis of 7-methylpurine derivatives. It was first made by E. Fischer [1] by the interaction of theobromine and phosphorus oxychloride in a sealed tube. However, because reactions in sealed glass tubes are unsatisfactory, we used another method, described by Davell [2], for the preparation of trichloropurine from uric acid, which consisted of reacting the latter with phosphorus oxychloride in the presence of dimethylaniline at the boiling point. In the synthesis of 2,6-dichloro-7-methylpurine we changed somewhat the reaction conditions and the workup of the product, the yield of which was 25%.

The ability of the chlorine atom at position 6 of the purine nucleus to be easily transformed into an amino group was the basis of our interest in the transformations of 2,6-dichloro-7-methylpurine. It is known that 2,6-dichloro-7-methylpurine reacts with alcoholic ammonia at 85-90° to give 2-chloro-6-amino-7-methylpurine [3], and at 110° it reacts analogously with diethylamine and other dialkylamines [4].

The data from our work showed that the chlorine atom at position 6 in the 2,6-dichloro-7-methylpurine molecule can be transformed into an amino-group in very mild conditions. Thus, on reaction with ethyleneimine or with an aqueous solution of diethanolamine at room temperature, 2-chloro-6-ethyleneimino-7-methylpurine or 2-chloro-6-diethanolamino-7-methylpurine was obtained.

It was further shown that it was relatively more convenient to carry out the reaction between 2,6-dichloro-7-methylpurine and an alcoholic solution of the corresponding amine under reflux. In these conditions, we also obtained 2-chloro-6-diethanolamino-7-methylpurine and, in addition, 2-chloro-6-monoethanolamino-7-methylpurine, the ethyl ester of N-(2-chloro-7-methylpurine-6-) glycocoll and the ethyl ester of N-(2-chloro-7-methylpurine-6-) dl-alanine.

It seemed interesting to synthesize derivatives of 6-amino-7-methylpurine which did not contain chlorine at position 2, i.e., substances whose structure simulated that of adenine.

To obtain these compounds, we used the method of E. Fischer, who described the reduction of 2-chloro-6-amino-7-methylpurine into 7-methyladenine [3] and 2-chloro-6-hydroxy-7-methylpurine into 7-methylhypoxanthine [1] by the action of hydroiodic acid (d 1.96) in the presence of phosphorus triiodide when heated on a water bath. It was shown that it is possible to simplify this method by using hydroiodic acid (d 1.5) and

by carrying out the reaction in the presence of red phosphorus at the boiling point of the mixture. Using these conditions 7-methyladenine, 7-methylhypoxanthine, and the ethyl ester of N-(7-methylpurine-6)-glycocoll were prepared. Both the last two compounds were isolated as their hydrochlorides. The ethyl ester of N-(7-methylpurine-6)-glycocoll was also synthesized from 6-chloro-7-methylpurine.

Unfortunately, we failed to reduce 2-chloro-6-diethylamino-7-methylpurine by this method. Desiring to obtain 6-diethanolamino-7-methylpurine, we carried out the condensation of 7-methyladenine with a considerable excess of ethylene oxide in 25% acetic acid by heating on a boiling-water bath for 11-12 hours. It appeared however, that only one mole of ethylene oxide took part in the reaction and 6-monoethanolamino-7-methylpurine was formed.

When we tried to obtain 2-hydroxy-6-diethylamino-7-methylpurine from 2-chloro-6-diethylamino-7-methylpurine by heating it with concentrated hydrochloric acid at 120-125°, 7-methylxanthine was formed. This reaction is obviously analogous to that described by E. Fischer [1] for 7-methyladenine.

2-Chloro-6-ethyleneimino-7-methylpurine, 2-chloro-6-diethylamino-7-methylpurine, 6-monoethanolamino-7-methylpurine, 7-methyladenine, 6-diethylamino-7-methylpurine, and the ethyl ester of N-(7-methylpurine-6)-glycocoll were investigated in the experimental chemotherapy laboratory. The results of this investigation will be reported separately.

EXPERIMENTAL

2,6-Dichloro-7-methylpurine. 50 g of theobromine was boiled with 300 ml of freshly distilled phosphorus oxychloride and 54 g of dimethylaniline on an oil bath for 8 hours. At the end of the heating period the phosphorus oxychloride was distilled in vacuum at a pressure not exceeding 20 mm. The residue was poured into 300 g of ice. Soda was added to the resulting solution until it was slightly acid to Congo Red and it was then left overnight. The precipitate formed was then filtered off, washed well with 2% sodium hydroxide and recrystallized from water with animal charcoal. 14.3 g (25%) of 2,6-dichloro-7-methylpurine with m. p. 195-196° was obtained. After a second recrystallization the m. p. was 195.5-196°. Literature data: m. p. 196-197° [1].

Found %: C 35.34; H 2.04; Cl 35.02. $C_6H_4N_4Cl_2$. Calculated %: C 35.47; H 1.99; Cl 34.92.*

2-Chloro-6-ethyleneimino-7-methylpurine. To a solution of 0.9 g of 2,6-dichloro-7-methylpurine in 600 ml water was added 0.5 g of ethyleneimine and 3 ml of 1% sodium hydroxide solution. The mixture obtained was allowed to stand for 18-20 hours and then the solvent was evaporated in vacuum at a temperature not higher than 40-45°. The residue was recrystallized from absolute methylated spirit. 0.45 g (49%) of 2-chloro-6-ethyleneimino-7-methylpurine was obtained. The substance was poorly soluble in water (0.05 g in 100 ml) and slowly decomposed without melting when heated to 360°.

Found %: C 46.16; H 4.07; N 33.65. $C_8H_8N_5Cl$. Calculated %: C 45.81; H 3.85; N 33.42.

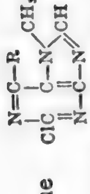
2-Chloro-6-diethylamino-7-methylpurine. A solution of 0.9 g of 2,6-dichloro-7-methylpurine and 2.4 g of diethanolamine in 600 ml of water was left at room temperature for 18-20 hours. The water was then evaporated off in vacuum at 35-45° and the residue washed with water, alcohol, and ether. The residue was dried and dissolved in absolute alcohol. The solution was left in a refrigerator, when an oil began to separate from the solution, and the oil crystallized after standing for many days. The substance was filtered off and recrystallized from absolute alcohol. After three consecutive recrystallizations 2-chloro-6-diethanolamino-7-methylpurine with m. p. 171-172.5° was obtained. The analytical sample was dried in vacuum over P_2O_5 at 84°.

2-Chloro-6-amino substituted 7-methylpurines (see table). A solution of 0.1 mole of 2,6-dichloro-7-methylpurine and 0.2 to 0.24 mole of the respective amine in 1200 ml of absolute alcohol were boiled for 2-2.5 hours. At the end of the heating the solution was left overnight and then the solvent was evaporated in vacuum.** The residues were recrystallized.

---

* Analyses carried out under the direction of A. D. Chinaev.

** In the preparation of 2-chloro-6-monoethanolamino-7-methylpurine the reaction product precipitated on standing. On the following day, it was filtered off without evaporation of the solvent.

2-Chloro-6-Amino Derivatives of 7-Methylpurine 

R	Empirical formula	M. p.	Solvent for recrystallization	Yield (%)	Found (%)			Calculated (%)		
					C	H	Cl	C	H	Cl
$N(CH_2CH_2OH)_2$	$C_{10}H_{14}O_2N_5Cl$	175°	Alcohol	56	44.33	5.32	13.04	44.19	5.20	13.06
$HNCH_2CH_2OH$	$C_8H_{10}ON_5Cl$	216—217	The same		42.43	4.49	15.95	42.17	4.45	15.65
$HNCH_2COOC_2H_5$	$C_{10}H_{12}O_2N_5Cl$	210 *	Water	75.5	44.25	4.42	13.01	44.53	4.48	13.14
$HNCH(CH_3)—COOC_2H_5$ **	$C_{11}H_{14}O_2N_5Cl$	70—71	The same	56.5			12.61 12.77			12.50
	$C_{11}H_{16}O_3N_5Cl$				43.45 43.74	5.45 5.37		43.78	5.40	

* M. p. obtained after drying in vacuum over P_2O_5 at 84°; before drying m. p. 198-199°.

** The compound crystallized with one molecule of water, which was removed on drying in a vacuum desiccator at 20°.

7-Methyladenine. A mixture of 2.4 g of 2-chloro-6-amino 7-methylpurine [4], 162 ml hydroiodic acid (d 1.50) and 8.4 g of red phosphorus was heated on a hot-plate for 10-13 minutes. At the end of the heating the mixture was cooled to room temperature, filtered from unreacted red phosphorus, and the hydroiodic acid evaporated off in vacuum. The residual material was recrystallized from hot water containing some crystalline hyposulfite. The hydroiodide separated from the solution on cooling; the former was filtered off and then added to a small quantity of concentrated ammonia solution, the mixture heated to boiling and left overnight. The residue was filtered off and twice recrystallized from boiling water. 10 g (51%) of 7-methyladenine with m. p. 345-356° (in a block) was obtained. Literature data: m.p. 351° [3].

Found %: C 48.26; H 4.75. $C_6H_7N_5$. Calculated %: C 48.29; H 4.73.

6-Diethylamino-7-methylpurine. The reduction of 2-chloro-6-diethylamino-7-methylpurine was carried out under exactly the same conditions and with exactly the same ratio (of reactants) as shown for 7-methyladenine, but a different method was used for working up the product. 4% sodium hydroxide solution was added to the residue after evaporation of the hydroiodic acid, until the solution was alkaline to phenolphthalein. The resulting solution was subjected to thorough extraction with chloroform. After drying with anhydrous sodium sulfate the chloroform was evaporated off in vacuum. The residue was dissolved in a small quantity of cold absolute alcohol. The solution was cooled with ice and HCl added until the solution was acid to Congo. A precipitate began to separate from the solution on scratching with a glass rod. The mixture was left in a refrigerator overnight, the precipitate filtered off and twice recrystallized from absolute alcohol. From 17 g of starting material with m. p. 198-199°, 7.3 g (43%) of 6-diethylamino-7-methylpurine hydrochloride was obtained which melted at 200.5-201.5° after being dried in vacuum over P_2O_5 at 84°.

Found %: C 49.74; H 6.89; Cl 14.57. $C_{10}H_{16}N_5Cl$. Calculated %: C 49.67; H 6.68; Cl 14.67.

Ethyl ester of N-(7-methylpurine-6)-glycocoll. a) From the ethyl ester of N-(2-chloro-7-methylpurine-6) glycocoll. The reaction was carried out under the same conditions and with the same weight ratios as described for 7-methyladenine. The residue after evaporation of hydroiodic acid was dissolved in boiling absolute alcohol and dry hydrogen chloride passed through the solution. Absolute ether was added to the solution obtained: In this way an oily substance separated. The mixture was left in the refrigerator overnight, when the substance slowly crystallized. The precipitate was filtered off, washed with a mixture of absolute alcohol and ether, then the ether and the substance was dried in a vacuum desiccator over alkali at 20°. 1.6 g (40%) of the ethyl ester of N-(7-methylpurine-6)-glycocoll hydrochloride was obtained from 4 g of the ethyl ester of N-(2-chloro-7-methylpurine-6)-glycocoll with m. p. 217-218° (decomp.).

Found %: C 44.06; H 5.27; Cl (ionic) 13.39; Cl (total) 13.06. $C_{10}H_{14}O_2N_5Cl$. Calculated %: C 44.20; H 5.19; Cl 13.06.

b) From 6-chloro-7-methylpurine. Gaseous nitrogen was passed for 20 minutes through a solution of 1.0 g of 6-chloro-7-methylpurine [5] in 30 ml alcohol in a steel autoclave cooled in ice. The flow of nitrogen was stopped and a solution of 1.5 g of glycocoll ethyl ester (made from the hydrochloride and freshly distilled) in a few milliliters of absolute alcohol added. The autoclave was heated for 7.5 hours at 128-130°. At the end of the heating period the solvent was evaporated in vacuum. The residue was dissolved in a small quantity of alcohol with heating. Alcoholic hydrochloric acid was added to the solution cooled in ice until the solution was acid to Congo Red, and then a small quantity of ether added until a precipitate separated. The mixture was left overnight in a refrigerator, after which the precipitate was filtered off. After crystallization from alcohol a small amount of the ethyl ester of N-(7-methylpurine-6) glycocoll with m. p. 213-215° (decomp.) was obtained.

6-Monoethanolamino-7-methylpurine. To a solution of 2 g of 7-methyladenine in 6 ml of 25% acetic acid cooled in ice, 5 ml (4.5 g) ethylene oxide was added. The mixture was heated in a sealed tube on a boiling-water bath for 11-12 hours. At the end of the heating period the solvent was evaporated in vacuum, the residue dissolved in a small quantity of absolute alcohol and an alcoholic solution of hydrochloric acid added until the ice-cooled mixture became acid to Congo Red. Absolute ether was added to the solution thus obtained until a precipitate appeared and the mixture left in a refrigerator overnight. The substance was filtered off, washed with ether and recrystallized twice from alcohol. 0.8 g (26%) of 6-monoethanolamino-7-methylpurine with m. p. 283-284° (decomp.) was obtained. After drying in vacuum over P_2O_5 at 84° the substance had m. p. 284-285°.

Found %: C 41.94; H 5.21; Cl 15.39. $C_8H_{12}ON_5Cl$. Calculated %: C 41.81; H 5.27; Cl 15.45.

On adding 1.2 ml of 1 N sodium hydroxide to 0.3 g of 6-monoethanolamino-7-methylpurine hydrochloride the substance dissolved and then a crystalline precipitate separated from the solution. After separating and washing the precipitate with alcohol, 6-monoethanolamino-7-methylpurine with m. p. 210-212° was obtained. The substance dissolved in alcohol and ether. On adding alcoholic hydrochloric acid to an alcoholic solution of the base the hydrochloride with m. p. 283-284° was obtained again.

7-Methylxanthine. A mixture of 1.4 g of 2-chloro-6-diethylamino-7-methylpurine and 15 ml concentrated hydrochloric acid in a sealed tube was heated to 120-125° for 3 hours. When the heating was completed the solution was evaporated to dryness on a water bath. The residual substance was washed with a large quantity of water and recrystallized from water. 7-Methylxanthine with m. p. greater than 360° was obtained. The substance gave a murexide reaction.

Found %: C 43.61; H 3.53. $C_6H_6O_2N_4$. Calculated %: C 43.38; H 3.64.

SUMMARY

A new method for preparing 2,6-dichloro-7-methylpurine is proposed. The method for preparing 7-methyladenine has been simplified. The following derivatives of 7-methylpurine which have not been previously described have been prepared and characterized: 2-chloro-6-ethyleneimino-7-methylpurine, 2-chloro-6-monoethanolamino-7-methylpurine, 2-chloro-6-diethanolamino-7-methylpurine, 6-diethylamino-7-methylpurine, 6-monoethanolamino-7-methylpurine, and the ethyl esters of N-(2-chloro-7-methylpurine-6)-glycocoll, N-(2-chloro-7-methylpurine-6)-dl- α-alanine, and N-(7-methylpurine-6)-glycocoll.

LITERATURE CITED

[1] E. Fischer, Ber. 30, 2400 (1897).

[2] J. Davell, J. Am. Chem. Soc. 73, 2937 (1951).

[3] E. Fischer, Ber. 31, 104 (1898).

[4] R. Adams and F. Whitmore, J. Am. Chem. Soc. 67, 127 (1945).

[5] R. Prasad and R. Robins, J. Am. Chem. Soc. 79, 6401 (1947).

A NEW ANTIBIOTIC FROM ACTINOMYCES FLUORESCENS

S. I. Denisova, L. P. Kucheryavenko, and G. P. Men'shikov

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 332-334, January, 1960

Original article submitted December 29, 1958

We have separated a new crystalline, optically inactive substance with m. p. 142-143° from the mycelia of an actinomycete strain No. 2703, belonging to the groups Actinomyces fluorescens and kindly given to us by the laboratory, directed by N. A. Krasil'nikov (Institute of Microbiology of the Academy of Sciences of the USSR).

The analytical data for this substance conforms well to the formula $C_{36}H_{54}O_{12}$. The accuracy of this formula, especially the number of hydrogen atoms, with such a large molecular weight could not be strictly established from the elementary analysis but, as shown later, the formula is confirmed by the results of hydrolytic decomposition of the substance.

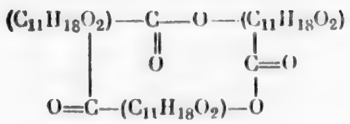
The substance obtained, called "fluorin," was investigated in the laboratory for the chemotherapy of infectious deceases of the All-Union Scientific-Research Chemicopharmaceutic Institute. In this way, it was shown that it had satisfactory activity *in vitro* against tubercle bacilli but this activity almost completely disappeared in blood serum. Fluorin is neutral and has no active hydrogen,as follows from the Tserevitinov analytical data.

On heating with alkaline alcoholic solution, it was hydrolyzed, and an ester value of 250 was found. This indicates the presence in the molecule of three complex ester groups because in this case in the formula $C_{36}H_{54}O_{12}$ (M 678.5) the calculated ester value should be equal to 249.

As the result of the hydrolysis of fluorin only one substance was formed, an acid of composition $C_{12}H_{20}O_5$. This was shown by a paper chromatographic study of the products and also by the almost quantitative yield of the acid.

Because the acid was obtained as a thick noncrystallizable oil, it was converted into its methyl ester with diazomethane in order to purify and characterize it. The ester was an equally thick oil,distilling at 88-90° (0.01 mm). The elementary analysis of this ester agreed well with the formula $C_{13}H_{22}O_5$. An active hydrogen determination showed the presence of only one hydroxyl group. The methyl ester did not contain a carbonyl group,which makes it very likely that the remaining two oxygen atoms are linked in simple ether groups. Then, the formula of the acid obtained can be shown in the following way: $C_{11}H_{18}O_2(OH)COOH$.

By comparing the empirical formulas of the antibiotic and the acid obtained from it, it can be seen that the first is built up from molecules of the acid but with the loss of three molecules of water. This confirms on one hand the empirical formula of the antibiotic, and on the other,the presence in the antibiotic of three complex ester groups. The fact that there is only one hydroxyl group in the acid obtained and the absence of an active hydrogen in the antibiotic compels one to the following conclusion: That the hydroxyl group formed during hydrolysis was esterified with the carboxylic acid group of a second acid in the antibiotic. Hence fluorin must be a cyclic complex ester formed from three molecules of the same hydroxy acid and having the following structure:



From the similarity between this schematic formula and the formula of longisporin — an antibiotic isolated and studied by one of us [1]–one may draw conclusions about the analogy of structure of these antibiotics, the only difference being that the new antibiotic has a much simpler structure. Its molecule is constructed from only one acid in contradistinction from longisporin. We are continuing the study of this acid.

The elementary analyses and determination of the functional groups for the data investigated were carried out by V. M. Rokova under the leadership of A. D. Chinaeva, to whom we extend our thanks.

EXPERIMENTAL

Isolation and Purification of the Antibiotic*

The damp mycelia, separated from the culture medium, were extracted several times with acetone, the mycelia being separated from the acetone each time by filtration. The acetone extracts, which were dark-brown in color, were combined and the acetone completely removed. The residue, which separated into an upper oily layer and a lower aqueous layer, was repeatedly extracted with ether. After removal of the ether from the ethereal extracts a thick oil remained, which partially crystallized when it was left in a refrigerator. The whole mass was transferred to a Buchner funnel and the uncrystallized oil carefully removed from the solid part. The heavily contaminated crystals were extracted with ether many times, and the ether was filtered each time from the very poorly ether-soluble dark-brown residue.** The ether extracts were combined and the solvent completely evaporated off. The residue crystallized completely on standing in a refrigerator. The crystals were washed first with a small quantity of ether and then with alcohol; they were recrystallized many times from methanol and ethanol alternately, the first recrystallizations using active carbon. The pure antibiotic crystallized in the form of glittering snowy needles with m. p. 142-143°. The substance was very soluble in chloroform, less so in ether; it was very soluble in hot methanol and ethanol, but insoluble in water. It was optically inactive.

Found %: C 64.09, 63.89; H 8.16, 8.18. M (by Rast) 686. $C_{36}H_{54}O_{12}$. Calculated %: C 63.68; H 8.03. M 678.5.

The saponification of fluorin. 8 g of the substance was boiled for 5 hours in 120 ml of 1 N alcoholic potassium hydroxide. The alcoholic solution was added to water and the alcohol completely distilled off. The alkaline aqueous solution was treated with 20% sulfuric acid until it was strongly acid to Congo Red and then extracted with ether. The ether extract was dried with sodium sulfate. After removal of the solvent, a slightly yellow noncrystallizable oil (about 8.5 g) remained, which gave only one spot, with R_f 0.23, when chromatographed on fast-filtering paper in the system n-butanol — water — acetic acid (5 : 5 : 1). The development of the chromatogram was carried out with alcoholic Bromphenol Blue. The methyl ester of the acid was prepared for purification and characterization of the acid. For this ester an ethereal solution of the acid was made to react with an excess of an ethereal solution of diazomethane. A rapid effervescence of nitrogen was observed. An oil distillable in vacuum remained after evaporation of the ether. Almost all of the oil distilled at 88-90° (0.01 mm).

Found %: C 60.26, 60.34; H 8.37, 8.52; OH 6.5, 7.0. $C_{13}H_{22}O_5$. Calculated %: C 60.42; H 8.59; OH 6.6.

SUMMARY

1. A new antibiotic called "fluorin" has been isolated from the mycelia of actinomycete 2703 of Actinomyces fluorescens; it has the composition $C_{36}H_{54}O_{12}$. It is optically inactive and has m. p. 142-143°.

* With the participation of E. Ya. Karaulova.

**An orange crystalline substance, m. p. 228-231°, was obtained from this residue, but because this substance had nothing in common with fluorin in its chemical nature, we shall report on it separately.

2. The sum total of the investigated chemical properties of fluorin indicate that this antibiotic, like the antibiotic longisporin [1] is a cyclic complex ester but, in contradistinction from longisporin, the molecule of the new antibiotic is constructed from only one hydroxy acid with the composition $C_{12}H_{20}O_5$.

LITERATURE CITED

[1] G. P. Men'shikov and M. M. Rubinstein, Zhur. Obshch. Khim. 26, 2035 (1956).

THE GLYCOALKALOID OF THE PLANT SOLANUM MEGACARPUM KOIDZ.

II. THE IDENTITY OF MEGACARPIDINE AND DIHYDROSOLASODINE

A. S. Labenskii

S. Ordzhonikidze All-Union Chemicopharmaceutical Scientific Research Institute

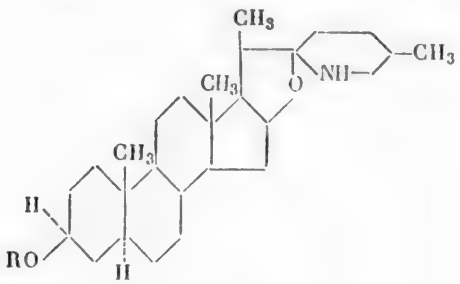
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 335-338, January, 1960

Original article submitted December 26, 1958

In our previous communication [1] it was shown that acid hydrolysis of the glycoalkaloid megacarpine, which is isolated from the leaves and young stems of Solanum megacarpum Koidz., yields a new aglycone, namely, megacarpidine with the composition $C_{27}H_{45}O_2N$. It was interesting to determine the nature of this new aglycone. The results of work in this direction are given below.

In an alcohol solution, megacarpidine forms a precipitate with digitonin. On the basis of this and also the fact that all known aglycones obtained from various plants of the potato family have a basic steroid structure, it could be surmised that the aglycone megacarpidine also has a structure of the same type. Only two steroid substances with the same composition as megacarpidine are known at the present time and these are tomatidine [2] and dihydrosolasodine [3]. As has already been stated in our first communication, megacarpidine and tomatidine are different substances. As regards dihydrosolasodine, up to now, it has not been found in nature and is a semisynthetic product, obtained by catalytic hydrogenation of the known steroidal alkaloid, solasodine [4].*

It was necessary to compare megacarpidine with dihydrosolasodine and this we did. By comparing the constants of dihydrosolasodine which have been published up to now in [3, 5-7] with the corresponding constants of megacarpidine which we found previously [1], it was impossible to determine whether these two substances are identical or not. The solution of the latter problem required a more detailed comparison of the properties of these substances. For this purpose, solasodine, which we prepared from Solanum aviculare Forst [8] and which had constants corresponding to literature data, namely, m. p. 199-201° and $[\alpha]^{20}D - 97.2 \pm 2°$ (methanol), was used to prepare dihydrosolasodine under conditions close to those reported by Briggs [3]. Having megacarpidine and dihydrosolasodine available, we were able to prepare a series of salts of these substances and also their mono- and diacetates under identical conditions. A comparison of the properties of the substances we obtained showed that megacarpidine and dihydrosolasodine are completely identical (see table).



* Note added during proofreading. At the time when our article was written we had not yet heard of the work of K. Schreiber, Planta medica 6, 93 (1958).

Constants of Megacarpidine, Dihydrosolasodine, and Their Derivatives

Alkaloid	Specific rotation		Melting point						
	in $CHCl_3$	in CH_3OH	base	hydrochloride	picrolonate	picrate*	perchlorate	mono-acetate	diacetate
Megacarpidine	−52.0 ± 2°	−54.3 ± 2°	208 —209°	298—299°	218 —219°	141—142°	231 —232°	214.5—215.5°	182—183°
Dihydrosolasodine	−50.0 ± 2	−54.4 ± 2	207.5—208.5	297—298	218.5—219.5	141—142	230.5—231**	214 —215	183—184.5

* The melting points of the picrates were determined on a Köfler block and those of the other substances, in a capillary. See experimental section.

** The melting point of dihydrosolasodine perchlorate given in [7] (141-142°) is very much lower than that which we found. The reason for this discrepancy is not clear to us.

In addition, the identity of megacarpidine and dihydrosolasodine was confirmed by the correspondence of their infrared spectra.*

Since the structure of solasodine has been established by the work of Briggs and his co-workers [7] and Uhle [9], the structure of the glycoalkaloid megacarpine may be expressed by the formula given here, in which R is a tetrasaccharide consisting of one molecule of glucose, one molecule of galactose, and two molecules of xylose.

It is interesting to compare our discovery of the aglycone megacarpidine, which is found to be identical with the hydrogenation product of the steroidal alkaloid solasodine, with the analogous discovery of the aglycone demissidine by Kuhn and Löw [10]. Demissidine, which is obtained by hydrolysis of the glycoalkaloid demissine, isolated from Solanum demissum, was found to be identical with dihydrosolanidine, the hydrogenation product of the previously known steroidal alkaloid solanidine [4]. On the basis of these two facts, it may be surmised that with further investigation of plants of the Solanum family, some of them may be found to contain more new analogous pairs of saturated and unsaturated steroidal alkaloids. Thus, for example, it is probable that plants may be found which contain Δ^5-tomatidenol-3β as the main steroidal alkaloid. This compound was found by Schreiber in a very small amount in Solanum tuberosum [11]. Due to its steric structure, which is similar to that of tomatidine [12], this alkaloid will probably be found to be a more convenient substance for the production of steroid hormones than solasodine [13, 14].

EXPERIMENTAL

Purification of megacarpidine. A 0.38 g sample of megacarpidine, which was prepared previously [1], was further purified by passing a solution of it in 25 ml of chloroform through a column with 15 g of Al_2O_3. The adsorbed megacarpidine was extracted by washing with chloroform (25-ml fractions). The third and fourth fractions contained the greatest amount of material (0.33 g). After recrystallization from methanol and drying (100°, 2 mm, P_2O_5), this residue had m. p. 208-209° and $[\alpha]^{20}D$ − 52.0 ± 2° (chloroform, c = 1.3).

Preparation of dihydrosolasodine. A solution of 7.0 g of solasodine in a mixture of 100 ml of alcohol and 20 ml of glacial CH_3COOH was shaken with 8 g of palladium on charcoal (containing 10% Pd) in a hydrogen atmosphere until the absorption of hydrogen ceased (12 hours). When aqueous ammonia was added to the filtered solution of the hydrogenation product, a white, crystalline precipitate (5.5 g)

* The infrared spectra of megacarpidine and dihydrosolasodine were obtained in the physicochemical laboratory of our institute under the direction of Yu. N. Sheinker.

formed immediately. It had m. p. 204-206° and $[\alpha]^{20}D$ − 61.6° (chloroform, c = 1.0). The dihydrosolasodine was purified by solution in a mixture of 55 ml of alcohol and 3 ml of CH_3COOH with subsequent addition of aqueous ammonia to the hot solution. This operation was carried out twice. The purified dihydrosolasodine had m. p. 207.5-208.5° and $[\alpha]^{20}D$ − 50.0 ± 2° (chloroform, c = 1.3) and 54.4 ± 2° (methanol, c = 0.5). The melting point of a mixture with megacarpidine was not depressed. It is interesting to note that a mixture of dihydrosolasodine and solasodine did not have a depressed melting point either and melted at a temperature midway between the melting points of the two components. The melting point of a mixture of megacarpidine and solasodine was not depressed either.

The hydrochlorides of megacarpidine and dihydrosolasodine were prepared by adding an alcohol solution of HCl to hot solutions of each of these substances in alcohol. The precipitates were recrystallized from 75% methanol. The melting point of the megacarpidine hydrochloride was 298-299° and that of the dihydrosolasodine hydrochloride, 297-298°. The melting point of a mixture of these salts was not depressed.

The picrolonates of the two substances compared were prepared by mixing alcohol solutions of each of the substances with alcohol solutions of picrolonic acid. Yellow, crystalline precipitates were obtained. Recrystallization from alcohol yielded needles in both cases. The melting point of megacarpidine picrolonate was 218-219° and that of dihydrosolasodine picrolonate, 218.5-219.5°. The melting point of a mixture of these salts was not depressed.

The picrates of the two substances were prepared by adding a saturated solution of picric acid in 50% alcohol to solutions of each of the substances compared, in a mixture of 50% alcohol and sufficient acetic acid for solution. The amorphous precipitates were recrystallized from 50% alcohol. The yellow crystals (prisms) obtained were readily soluble in alcohol. The picrates of the two substances behaved identically on melting. When melted in a capillary, they softened at 142°, but the product was not clear at this temperature. The product became clear at approximately 152°. When a Kofler block was used, the m. p. was 141-142°. The melting point of a mixture of the two picrates was not depressed.

The perchlorates of the substances compared were prepared in the following way. A 30% solution of $HClO_4$ was added dropwise to mixtures of each of the substances compared, with a 20-fold amount of alcohol until an acid reaction to methyl orange was produced. The substances dissolved with stirring. Water was added to the clear solutions until turbidity appeared. On standing, the solutions deposited crystalline precipitates. After the precipitates had been collected and dried (100°, 2 mm, P_2O_5), megacarpidine perchlorate had m. p. 231-232° and dihydrosolasodine perchlorate, m. p. 230.5-231°. The melting point of a mixture of the two perchlorates was not depressed.

Megacarpidine and dihydrosolasodine monoacetates were prepared according to the directions of Rochelmeyer et al., [6] by treating pyridine solutions of the two substances with acetic anhydride without heating. The precipitates obtained were recrystallized from acetone. The melting point of megacarpidine monoacetate was 214.5-215.5° and that of dihydrosolasodine monoacetate, 214-215°. The melting point of a mixture of these monoacetates was not depressed.

Megacarpidine and dihydrosolasodine diacetates were prepared according to the directions of Briggs et al. [5], by heating pyridine solutions of these substances with acetic anhydride. The precipitates were recrystallized from acetone. The melting point of megacarpidine diacetate was 182-183° and that of dihydrosolasodine diacetate, 183-184.5°. (The precipitates were probably not quite pure, but further purification was not carried out due to the small amounts of the substances obtained.) The melting point of a mixture of the diacetates obtained was not depressed.

SUMMARY

The aglycone megacarpidine, obtained by hydrolysis of the glycoalkaloid megacarpine, is identical with dihydrosolasodine.

LITERATURE CITED

[1] A. S. Labenskii, I. I. Gerasimenko, and L. M. Utkin, Zhur. Obshchei Khim. 28, 3120 (1958).

[2] T. D. Fontaine, I. S. Ard, and R. M. Ma, J. Am. Chem. Soc. 73, 878 (1951).

[3] L. H. Briggs, R. P. Newbold, and N. E. Stace, J. Chem. Soc. 1942, 3.

[4] V. Prelog and O. Jeger, "The Chemistry of Solanum and Veratrum Alkaloids" in the book: R. H. F. Manske, and H. L. Holmes, The Alkaloids, III (New York, 1953).

[5] L. H. Briggs and T. O'Shea, J. Chem. Soc. 1952, 1654.

[6] H. Rochelmeyer, H. Stützel, and H. Chen, Archiv. Pharm. 282, 92 (1944).

[7] L. H. Briggs, W. E. Harvey, et al., J. Chem. Soc. 1950, 3013.

[8] R. Kuhn, J. Löw, and H. Trischman, Ber. 88, 289 (1955).

[9] F. C. Uhle, J. Am. Chem. Soc. 75, 2280 (1953).

[10] R. Kuhn and J. Löw, Ber. 80, 406 (1947).

[11] K. Schreiber, Angew. Chem. 69, 483 (1957).

[12] F. C. Uhle and J. A. Moore, J. Am. Chem. Soc. 76, 6412 (1954).

[13] Y. Sato, H. G. Latham, Jr., and E. Mosettig, J. Org. Chem. 22, 1496 (1957).

[14] N. N. Suvorov, Med. Prom. 3, 22 (1956).

ALKALOIDS OF HAPLOPHYLLUM FOLIOSUM VVED. STRUCTURE OF DUBINIDINE

G. P. Sidyakin, M. Eskairov, and S. Yu. Yunusov

Institute of the Chemistry of Plant Materials, Academy of Sciences, Uzb. SSR

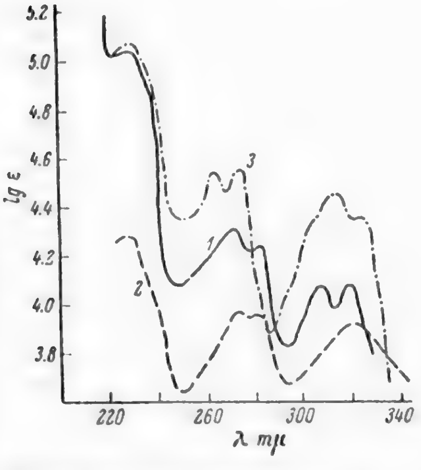
Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 338-345, January, 1960

Original article submitted October 29, 1958

Continuing the chemical study of plants of the genus Haplophyllum A. Juss. (Rutaceae family) [1], we investigated another species of this genus, namely, Haplophyllum foliosum Vved.

This semishrub, which grows in shallow soil on the slopes of the southern part of the Palmir-Alai region at a height of 600-1400 m [2], was collected between Kulyab and Dangara (Tadzhik SSR) at the end of flowering and the beginning of fruit bearing (July 2-8).

It was established that the dried leaves contained 2%, the stems 0.4%, the unripe seeds 1.53%, the root cortex 0.16%, and the root without cortex 0.037% of alkaloids. The whole of the above-ground part contained 0.61% of alkaloids. Four alkaloids were isolated from the above-ground part of the plant. One of them was found to be identical with dubinidine, which we isolated for the first time from Haplophyllum dubium Eug. Kor. [1]. Experimental data from the determination of the composition of dubinidine led to the formula $C_{15}H_{17}O_4N$ or, in a developed form, $C_{14}H_{12}ON(OH)_2(OCH_3)$.



Ultraviolet absorption spectra. 1) Dubinidine; 2) dihydroflindersine; 3) 4-methoxyquinoline-2.

Dubinidine is optically active; it gives readily crystallizable salts, namely, the hydrochloride, hydrobromide, hydroiodide, and nitrate. Both hydroxyl groups are secondary alcohol groups and the nitrogen is tertiary. The fourth oxygen atom has an indifferent character. This compound is saturated and is not reduced by zinc in hydrochloric acid, or hydrogenated over a platinum catalyst. The ultraviolet spectrum of dubinidine is similar to that of dihydroflindersine, an alkaloid with a pyranoquinoline structure [3] (see figure).

When heated with methyl iodide in methanol or in a sealed tube without solvent, dubinidine formed the methiodide of the base. The action of alcoholic alkali on the latter yielded an iso-compound (II) [4], which had an NCH_3 group and did not contain a methoxyl group. This type of isomerization has also been observed for the alkaloids cusparine [5] and 2-phenyl-4-methoxyquinoline [6].

The formation of isodubinidine gives grounds for assuming that dubinidine (I) is a quinoline derivative with a methoxyl group in the α or γ position.

Further data on the structure of dubinidine were obtained by studying the oxidative decomposition products. Oxidation with potassium permanganate in acetone led to the aldehyde $C_{11}H_9O_3N$, which was converted by further oxidation into the acid $C_9H_5ON(OCH_3)(COOH)$ (III). The acid (III) was similar in properties and composition to dictamnic acid [7] and this was confirmed by direct comparison of the methyl ester of this acid with synthetic methyl dictamnate [3, 8]. Decarboxylation of acid (III) led to 4-hydroxyquinolone-2 [3, 9] and oxidation of this yielded anthranilic acid. Consequently, the foundation of the dubinidine molecule is a quinoline ring with a methoxyl group in the γ position and the $C_5H_{10}O_3$ residue is attached to this.

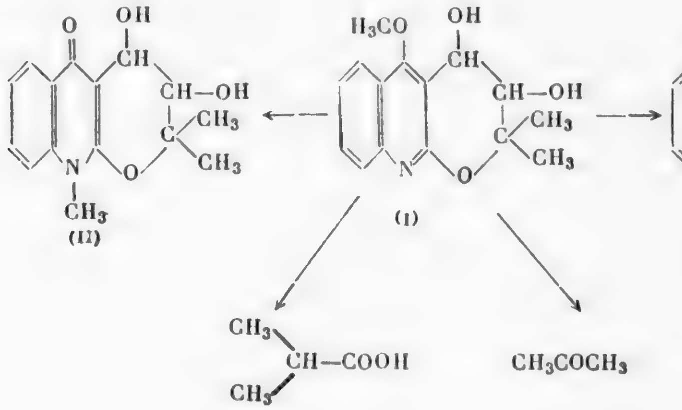
The presence of the carboxyl group in position 3 of the dictamnic acid molecule and the carbonyl group in position 2 of the quinoline ring shows that the $C_5H_{10}O_3$ residue is at the given carbon atoms. The fact that the dictamnic acid formed is optically inactive shows that the optical center is located in the oxidizable part of the alkaloid, i.e., in the $C_5H_{10}O_3$ residue. The two hydroxyl groups must be here also.

To determine whether a CCH_3 or a CH_3CCH_3 group was present, dubinidine was oxidized with chromic acid in sulfuric acid. Less than 1 mole of acetic acid was formed in this case. However, when the alkaloid was oxidized more carefully with the same reagent, acetone was obtained, indicating the presence of a CH_3CCH_3 group in the $C_5H_{10}O_3$ residue.

Oxidation of the dubinidine molecule with two atoms of oxygen yielded isobutyric acid. This shows that the $C_5H_{10}O_3$ residue forms a dimethyldihydropyran ring with the quinoline nucleus (in the α, β position).

Dubinidine is oxidized by periodic acid [10] when 1 mole of periodic acid is consumed in the oxidation of 1 mole of alkaloid. Consequently, the hydroxyl groups in the dubinidine molecule must be on neighboring carbon atoms.

The ease with which dictamnic acid is formed excludes the possibility of the CH_3CCH_3 group lying at the fifth carbon atom and the hydroxyl groups being at positions 2 and 3 of the pyranoquinoline ring. Therefore, the structure of dubinidine must be expressed by the formula of 2,2-dimethyl-3,4-dihydroxy-5-methoxy- α,β-dihydropyranoquinoline (I), which explains all its chemical properties well.



The second alkaloid which we isolated from H. foliosum was identical with skimmianine, which was first obtained from the Japanese plant Skimmia japonica Thunb. (Rutaceae family) [11] and also from some species of unifoliates (see [1]). We also found skimmianine in the unripe seeds of H. foliosum, where it represented 30.4% of the total alkaloids or 0.47% of the seed weight [12].

The two remaining alkaloids were found to differ from all other bases described in the literature up to the present and we therefore named them foliosine [12] and foliosidine [13].

Foliosine has the composition $C_{17}H_{15}O_3N$, is optically inactive, and gives a series of crystalline salts, namely, the hydrochloride, hydrobromide, hydroiodide, nitrate, and perchlorate. As functional groups, it contains methylimide and methylenedioxy groups. No methoxyl groups are present and the third oxygen atom has an indifferent character. Consequently, the developed formula of foliosine must have the following form:

$$C_{15}H_{10}O(NCH_3)(CH_2O_2) \qquad \text{(IV)}$$

Foliosidine has the composition $C_{17}H_{23}O_5N$. This optically active substance is a weak base. It gives a crystalline hydrochloride, hydrobromide, and picrate. The substituent groups of foliosidine include a methoxyl, methylimide, and two alcoholic hydroxyl groups. The presence of the latter was demonstrated by the preparation of a diacetyl derivative. No methylenedioxy group was detected qualitatively. Thus, the formula of foliosidine may be developed in the following way: $C_{15}H_{15}O_2(NCH_3)(OCH_3)(OH)_2$ (V).

EXPERIMENTAL

Extraction of alkaloids from the plant. The powdered, above-ground part of H. foliosum (12 kg) was moistened with 7% ammonia solution and extracted with chloroform in a continuous apparatus. The chloroform extract was treated with sulfuric acid. When the acid solution was made alkaline with gaseous ammonia, a precipitate (11.41 g) formed. Alkaloids were extracted with chloroform from the aqueous mother liquor (solution A). Removal of the solvent left 61.5 g of partially crystallized total bases. The over-all yield of total alkaloids was 72.91 g (0.61% of the plant weight).

Dubinidine

The precipitate (11.41 g) which formed when the acid solution was made alkaline was dissolved in acetone and the solution made weakly acid with an alcohol solution of hydrochloric acid. The base hydrochloride formed was separated by suction (yielding acetone mother liquor B) and dried. We obtained 9.16 g of hydrochloride with m. p. 192-193°. After the substance had been recrystallized twice from a mixture of alcohol and ether, the melting point had risen to 195-196°. A mixture with dubinidine hydrochloride melted at the same temperature. $[\alpha]^{18}D$ − 53.92° (c= 2.342, methanol).

Found %: C 57.47; H 6.24; N 4.79; Cl 10.36; OCH_3 8.81. $C_{15}H_{17}O_4N \cdot HCl$. Calculated %: C 57.77; H 5.82; N 4.49; Cl 11.38; OCH_3 9.95.

The addition of concentrated ammonia solution to an aqueous suspension of dubinidine hydrochloride precipitated the colorless base, which had m. p. 132-133° after recrystallization from acetone and did not depress the melting point of dubinidine isolated from H. dubium. $[\alpha]^{26.5}D$ − 62.95° (c=3.560, ethanol).

Found %: C 65.42; H 6.34; N 5.10; OCH_3 9.82; OH 12.60. $C_{15}H_{17}O_4N$. Calculated %: C 65.44; H 6.23; N 5.09; OCH_3 11.27; 2OH 12.35.

Ultraviolet spectrum (plotted with an SF-4 spectrophotometer). A 0.0001% alcohol solution of dubinidine showed λ_{max} 230 (log ε 5.04), 272 (log ε 4.30), 284 (log ε 4.24), 308 (log ε 4.07), 320 mμ (log ε 4.08).

Dubinidine hydrobromide. A solution of 0.5 g of dubinidine in 10 ml of methanol was acidified with concentrated hydrobromic acid. The addition of 3 ml of ether precipitated dubinidine hydrobromide in the form of needles clustered in rosettes. The yield was 0.6 g. After recrystallization from a mixture of methanol and ether, the product had m. p. 197-198°. It was readily soluble in water, alcohol, and methanol , but insoluble in acetone and ether.

Found %: Br 23.90. $C_{15}H_{17}O_4N \cdot HBr$. Calculated %: Br 22.44.

Dubinidine hydroiodide was prepared by acidification of a methanol solution of dubinidine with hydriodic acid and dilution with ether; it had m. p. 161-162° (with frothing). $[\alpha]^{18}D$ − 47.32° (c=1.760, methanol).

Found %: I 29.45. $C_{15}H_{17}O_4N \cdot HI$. Calculated %: I 31.47.

Dubinidine nitrate precipitated when a solution of 1 g of the base in 12 ml of methanol was acidified with nitric acid (with the use of ether) and formed needles with m. p. 176-177°. The yield was 1.1 g. $[\alpha]^{22}D$ − 52.39° (c=2.548, methanol).

Found %: C 52.86; H 5.81. $C_{15}H_{17}O_4N \cdot HNO_3$. Calculated %: C 53.25; H 5.36.

Dubinidine methiodide. 3 g of base was dissolved in 15 ml of methanol and heated with 2 ml of methyl iodide on a water bath. The methiodide (4.2 g) precipitated when the solution was cooled. Recrystallization from methanol gave colorless needles with m. p. 153-154°.

Found %: C 46.09; H 4.76; N 2.94; I 30.36; OCH_3 7.63. $C_{15}H_{17}O_4N \cdot CH_3I$. Calculated %: C 46.05; H 4.83; N 3.35; I 30.43; OCH_3 7.45.

Diacetyldubinidine. A mixture of 0.5 g of dubinidine and 6 ml of acetyl chloride was kept for 8 days in a sealed tube. The tube was then opened, the excess acetyl chloride removed in vacuum, and the residue dissolved in water. The solution was made alkaline with 4% ammonia solution and shaken with chloroform; removal of the solvent from the extract left a slightly colored oil (0.56 g), which crystallized when ether was added. After recrystallization from ether, the product had m. p. 108-109°. $[\alpha]^{19}D - 47.70°$ (c=2.610, ethanol).

Found %: C 63.28; H 5.94; N 3.70. $C_{15}H_{15}O_4N(CH_3CO)_2$. Calculated %: C 63.45; H 6.12; N 3.89.

The original base was formed when diacetyldubinidine was heated with a methanol solution of potassium hydroxide.

Isodubinidine. 0.5 g of dubinidine methiodide was heated with 5 g of potassium hydroxide and 15 ml of methanol on a water bath for 3 hours. The methanol was then evaporated, 10 ml of water added to the residue, and the base extracted with ether. Isodubinidine (0.3 g) precipitated when the ether solution was concentrated. It formed needles with m. p. 214-215° when recrystallized from methanol (1:5). The product was readily soluble in alcohol and methanol and less so in ether and acetone. $[\alpha]^{25}D + 21.05°$ (c=1.644, ethanol).

Found %: C 65.32; H 6.25; N 4.89; NCH_3 7.32. $C_{15}H_{17}O_4N$. Calculated %: C 65.44; H 6.23; N 5.09; NCH_3 10.58.

Isodubinidine hydrochloride (prepared in methanol) had m. p. 221-223° (with decomp.).

Oxidation of dubinidine with potassium permanganate in acetone. A solution of 9.18 g of potassium permanganate in 600 ml of acetone was gradually added over a period of 6 hours to 6 g of alkaloid in 500 ml of acetone heated gently on a water bath; then the hydrated manganese dioxide was removed, and the filtrate concentrated and poured into a dish. Complete evaporation of the acetone yielded 2.65 g of the aldehyde dictamnal. The hydrated manganese dioxide was treated with a 4% solution of potassium hydroxide and hot water. The alkaline and aqueous extracts were combined and acidified with 15% hydrochloric acid. The precipitated dictamnic acid (1.4 g) was recrystallized from methanol, when it had m. p. 260-262° (decomp.). The same acid was obtained by oxidation of dictamnal with potassium permanganate in acetone.

Methyl dictamnate. 0.15 g of the acid was suspended in absolute ether and methylated with an ether solution of diazomethane. The rhombic platelets (from alcohol) had m. p. 185-186°. A mixture with a synthetic sample melted at the same temperature.

Determination of C-methyl group in dubinidine. Steam distillation of the oxidation products from 1 g of alkaloid, 20 g of chromium trioxide, and 20 ml of concentrated sulfuric acid in 80 ml of water yielded 0.0912 g of acetic acid (43.43% of the calculated amount). The anilide had m. p. 113-114°. A mixed melting point with acetanilide was not depressed.

Oxidation of dubinidine with chromic acid. Isolation of acetone. 5 g of dubinidine was dissolved in a mixture of 20 g of chromium trioxide, 20 ml of concentrated sulfuric acid, and 150 ml of water, and heated on a water bath for 5 hours. Then 150 ml of liquid was steam distilled from the reaction mixture. The distillate was made alkaline with sodium hydroxide and 25 ml of liquid was steam distilled from it. To the distillate was added 20 ml of ethanol, 10 ml of a 10% solution of sodium hydroxide, and 4 g of freshly distilled benzaldehyde. On standing overnight, the solution deposited yellow crystals with m. p. 111-112° (from alcohol), which did not depress the melting point of dibenzalacetone.

Oxidation of dubinidine with potassium permanganate in an acid medium. To 4 g of alkaloid, dissolved in 44 ml of 1 N sulfuric acid, was added a solution of 2 g of potassium permanganate in 150 ml of water. The hydrated manganese dioxide was removed and the filtrate extracted repeatedly with ether. Evaporation of the ether left a semiliquid mixture, which was treated with 5% soda solution. The filtered soda solution was acidified with hydrochloric acid and extracted with ether and the ether distilled from the extract with a fractionating

column. The residue, which was a liquid with a sharp smell (0.5 ml), was heated with 1 ml of aniline and a few drops of pyridine for 2 hours at 160-180°. The pyridine was removed by heating on a water bath and the crystalline residue recrystallized from aqueous alcohol to give a product with m. p. 100-101°. A mixture with isobutyranilide melted at 102-103°.

Oxidation of dubinidine with periodic acid. Solutions of 0.550 g of dubinidine in aqueous methanol (5 ml of water and 15 ml of methanol) and 0.6126 g (0.5158 g calculated on anhydrous acid) of periodic acid in 5 ml of water were mixed and left at room temperature. After a day, the solution was filtered and the filter washed with water. The total volume of solution obtained was 30 ml.

To 20 ml of this solution were added 1.5 g of sodium bicarbonate, 20 ml of 0.1 N sodium arsenite, and 1 ml of 20% potassium iodide solution. The mixture was titrated with 0.01 N iodine solution. The titration required 106.5 ml of iodine solution, which corresponds to 0.0892 g of periodic acid or 0.1338 g in the whole volume of the reaction mixture. The amount of periodic acid consumed in the oxidation was 0.3820 g. The calculated amount was 0.3840 g.

Skimmianine

The total alkaloids (61.5 g) obtained from the aqueous mother liquor A by extraction with chloroform were ground with acetone and the crystals of skimmianine liberated (6.42 g) were separated by suction, yielding acetone mother liquor C. The melting point of the skimmianine was 175-176° (from alcohol).

Foliosine

The solvent was distilled from the combined acetone mother liquors B and C and the residue (57 g) dissolved in 10% hydrochloric acid. The acid solution was made alkaline with ammonia and the alkaloids extracted with chloroform. Distillation of the solvent from the chloroform extract yielded 50.5 g of bases. This mixture of alkaloids was dissolved in methanol and the solution acidified with alcoholic hydrochloric acid and cooled to −10 to −15°. Dilution with a three-fold amount of acetone precipitated crystals of alkaloid hydrochloride (3 g). On standing, the mother solution deposited a further 2.1 g of hydrochloride. The total yield was 5.1 g and the m. p. 242-245°. The addition of 25% ammonia to an aqueous suspension of the hydrochloride liberated colorless foliosine. The needles (from dilute alcohol) had m. p. 188-189°. $[\alpha]_D \pm 0$ (c=1.946, chloroform).

Found %: C 72.75; H 4.92; N 5.32; NCH_3 12.58. M 281.97. $C_{17}H_{15}O_3N$. Calculated %: C 72.57; H 5.37; N 4.98; NCH_3 10.32. M 281.29.

Foliosine hydrochloride was obtained by acidification of a methanol solution of the base with alcoholic hydrochloric acid. After recrystallization from a mixture of alcohol and ether, the product had m. p. 253-254°. It was readily soluble in alcohol and methanol and difficultly so in water.

Found %: Cl 11.26. $C_{17}H_{15}O_3N \cdot HCl$. Calculated %: Cl 11.18.

Foliosine hydrobromide. A solution of 0.2 g of base in 5 ml of methanol was made weakly acid with concentrated hydrobromic acid. The hydrobromide was induced to crystallize by rubbing with a rod. The yield was 0.23 g. The needles (from methanol) had m. p. 249-250° (decomp.).

Found %: Br 24.23. $C_{17}H_{15}O_3N \cdot HBr$. Calculated %: Br 22.00.

Foliosine hydroiodide. A solution of 0.3 g of foliosine in 10 ml of methanol was acidified with hydriodic acid. The hydroiodide (0.4 g) precipitated immediately. The lustrous needles (from methanol) had m. p. 225-226° (decomp.).

Found %: I 31.40. $C_{17}H_{15}O_3N \cdot HI$. Calculated %: I 31.01.

Foliosine nitrate. Acidification of a chloroform solution of 0.2 g of the alkaloid with concentrated nitric acid yielded the nitrate (0.25 g) as colorless needles. After recrystallization from alcohol, the product had m. p. 170-171.5° (decomp.).

Found %: C 59.70; H 4.25; N 7.84. $C_{17}H_{15}O_3N \cdot HNO_3$. Calculated %: C 59.29; H 4.65; N 8.16.

Foliosine methiodide was obtained by heating the alkaloid with excess methyl iodide in a sealed tube at 100°. The pale yellow platelets (from methanol) had m. p. 210-211°.

Found %: I 28.50. $C_{17}H_{15}O_3N \cdot CH_3I$. Calculated %: I 30.00.

Foliosine perchlorate was formed by the addition of an aqueous solution of sodium perchlorate to a solution of base in 10% sulfuric acid. The colorless crystals had m. p. 229-231° (decomp.).

Foliosidine

The alkaloids were extracted with chloroform from 40 kg of leaves with a small amount of fine stems and flowers. Analogous treatment of the chloroform extract yielded 700 g of total alkaloids (1.75% of the plant weight). Separation of the mixture as in the first extraction yielded 59.2 g of dubinidine (0.148% of the plant weight), 58 g of skimmianine (0.145% of the plant weight), and 28 g of foliosine (0.07% of the plant weight). The residue (from the mother liquor) weighed 545 g. This was dissolved in 10% sulfuric acid, the acid solution saturated with gaseous ammonia, and the alkaloids extracted with ether and then chloroform. The ether extracted 78.5 g and the chloroform, 450 g of the total bases. The ether fraction was dissolved in acetone and the solution acidified with hydrobromic acid solution. Cooling the acidified solution to −10 to −15° precipitated a mixture of hydrobromides (25.8 g), which was dissolved in water and the solution made alkaline with 25% ammonia solution. Dubinidine (1.8 g) precipitated and the remaining alkaloids were extracted first with ether and then with chloroform. The ether extracted an insignificant fraction of the alkaloids, while the chloroform extracted the bulk (15.5 g) as a slightly colored oil. Triturating this oil with acetone precipitated crystals of foliosidine (9 g or 0.023% of the plant weight). The m. p. was 141-142° (from acetone), $[\alpha]^{25}D$ + 41.62° (c=3.006, ethanol).

Found %: C 63.31; H 6.96; N 4.33; OCH_3 10.04; NCH_3 8.59. $C_{17}H_{23}O_5N$. Calculated %: C 63.53; H 7.21; N 4.36; OCH_3 9.65; NCH_3 9.02.

The foliosidine crystallized from a mixture of methanol and water (1:5) in the form of long needles with m. p. 60-62° (turbid melt).

Found %: H_2O 2.63. $C_{17}H_{23}O_5N \cdot 0.5\,H_2O$. Calculated %: H_2O 2.72.

Foliosidine hydrobromide was obtained by acidification of a methanol solution of base with HBr and dilution with ether and had m. p. 167-168° (with frothing). The product was readily soluble in water, alcohol, and methanol.

Found %: C 50.60; H 5.75; N 3.21; Br 20.46. $C_{17}H_{23}O_5N \cdot HBr$. Calculated %: C 50.74; H 5.77; N 3.48; Br 19.87.

Foliosidine hydrochloride was obtained by acidification of an alcohol solution of the alkaloid with alcoholic hydrochloric acid and had m. p. 162-164°. It was readily soluble in water and alcohol.

Foliosidine picrate precipitated when alcohol solutions of foliosidine and picric acid were mixed and had m. p. 182-183° (from alcohol).

Diacetylfoliosidine was obtained in the same way as diacetyldubinidine. The lustrous platelets (from acetone) had m. p. 129-130°. $[\alpha]^{18}D$ + 14.95° (c=1.160 , ethanol).

Found %: C 62.40; H 6.64; N 3.45. $C_{17}H_{21}O_5N(CH_3CO)_2$. Calculated %: C 62.22; H 6.72; N 3.45.

Ultraviolet spectrum. A 0.016% alcohol solution of foliosidine showed λ_{max} 234 (log ϵ 4.94), 252 (log ϵ 4.92), 324 (log ϵ 3.98), 234 mμ (log ϵ 3.84).

SUMMARY

1. The following alkaloids were extracted from the above-ground part of Haplophyllum foliosum Vved.: skimmianine, dubinidine, $C_{14}H_{12}ON(OCH_3)(OH)_2$, which we described previously, and two new alkaloids, namely, foliosine $C_{15}H_{10}O(NCH_3)(CH_2O_2)$ and foliosidine $C_{15}H_{15}O_2(NCH_3)(OCH_3)(OH)_2$.

2. Dubinidine has the structure of 2,2-dimethyl-3,4-dihydroxy-5-methoxy-α,β-dihydropyranoquinoline.

LITERATURE CITED

[1] S. Yu. Yunusov and G. P. Sidyakin, Zhur. Obshchei Khim. 22, 1055 (1952);* 25, 2009 (1955);* Doklady Akad. Nauk Uzb. SSR 12, 15 (1950).

[2] Flora SSSR 14, 216 (1949).

[3] R. F. C. Brown, J. J. Hoobs, L. K. Huges, and E. Ritchie, Austral. J. Chem. 7, 4, 348 (1954).

[4] L. Knorr, Ber. 30, 929, 937 (1897); A. P. Orekhov, Chemistry of the Alkaloids [In Russian] (Acad. Sci. USSR Press, 1955), p. 208.

[5] T. A. Henry, The Chemistry of Plant Alkaloids [Russian translation] (State Chem. Press, 1956), p. 451.

[6] G. Sidney, A. F. Smith, and E. C. Horning, J. Am. Chem. Soc. 79, 2239 (1957).

[7] V. Asahina, T. Ohta, and M. Jnubuse, Ber. 63, 2045 (1930).

[8] G. Koller, Ber. 60, 1108 (1927).

[9] F. Arndt, L. Erhgener, and O. Kutlu, Ber. 86, 951 (1953).

[10] Organic Reactions [Russian translation] (Foreign Lit. Press, 1950), Coll. 2, p. 362.

[11] J. Honda, Zbl. 1904, II, 1511.

[12] M. Eskairov, G. P. Sidyakin, and S. Yu. Yunusov, Doklady Akad. Nauk Uzb. SSR 2, 21 (1957).

[13] M. Eskairov, G. P. Sidyakin, and S. Yu. Yunusov, Doklady Akad. Nauk Uzb. SSR 5, 23 (1958).

* Original Russian pagination. See C. B. translation.

STRUCTURE OF THE ALKALOID MACROPHYLLINE

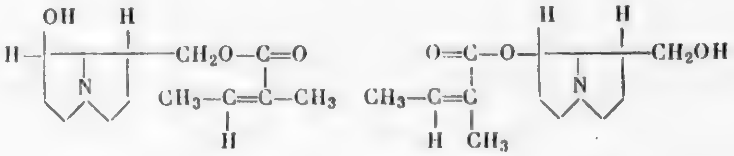
A. V. Danilova and L. M. Utkin

S. Ordzhonikidze All-Union Chemicopharmaceutical Scientific Research Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 345-348, January, 1960

Original article submitted December 23, 1958

The alkaloid macrophylline was isolated by us from the Caucasian plant Senecio macrophyllus [1]. The composition of macrophylline is $C_{13}H_{21}O_3N$. Hydrolysis of macrophylline yields an amino glycol (macronecine) with the composition $C_8H_{15}O_2N$ and angelic acid. One of the two hydroxyl groups of macronecine is esterified by the angelic acid and the other is free. Considering that most of the alkaloids from Senecio are based on a pyrrolizidine ring, two possible structural formulas, (I) and (II), may be put forward for macrophylline and (I) is more probable on the basis of all available data on the structure of pyrrolizidine alkaloids.



(I) (II)

As we have already reported, the amino glycol macronecine differs in properties from amino glycols with the composition $C_8H_{15}O_2N$ which have been described, namely platynecine, dihydroxyheliotridine, chastanecine, and turneforcidine [1].

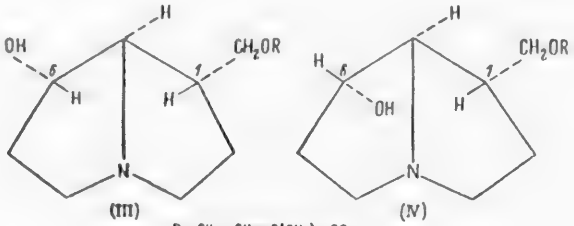
In order to study the structure of macrophylline, we reduced it catalytically and then replaced the free hydroxyl group in the hydromacrophylline obtained by chlorine, by treatment with $SOCl_2$. Attempts to replace the chlorine by hydrogen in the presence of Raney nickel and platinum from platinum oxide under various conditions were unsuccessful. The chlorine could be removed by metallic sodium in isoamyl alcohol with simultaneous saponification of the ester grouping of the alkaloid, and as a result we obtained a liquid amino alcohol with the composition $C_8H_{15}ON$ and a specific rotation of +19.75°. The amino alcohol formed crystalline salts, namely, the picrate, picrolonate, and methiodide. The properties of the amino alcohol and its salts coincided with those of laburnine, isolated by Galinovsky from the plant Cytisus laburnum [2]. The picrolonate of the amino alcohol we obtained did not depress the melting point of the picrolonate of laburnine, obtained by reducing the ethyl ester of D-trachelantamidate [3].

Laburnine differs in properties from known amino alcohols with a 1-hydroxymethylpyrrolizidine structure, namely, isopetronecanol [4], lindelophidine [5], and trachelantamidine [6].

On the basis of a comparison of the properties of laburnine and trachelantamidine, Galinovsky put forward the hypothesis that they are antipodes. The structure of trachelantamidine and the fact that it belongs to the L-pseudoheliotridane group were established by G. P. Men'shikov and G. M. Borodina [7]. From all that has been stated, it follows that macrophylline is an alkaloid of the D-pseudoheliotridane series and that the steric disposition

of the substituents at C_1 of macrophylline corresponds to that of pseudoheliotridane and trachelantamidine [8]. The second hydroxyl group of macrophylline is apparently at position 6 of the pyrrolizidine ring since macronecine is a diastereoisomer of platynecine and dihydroxyheliotridane, which have hydroxyl groups in positions 1 and 6 of the pyrrolizidine ring. The steric configuration of the substituents at C_6 of macrophylline remains undetermined and the compound may have structure (III) or (IV).

It is interesting to note that the fact that macronecine belongs to the pseudoheliotridane series, which we established, agrees with the hypothesis of Culvenor and Smith [9].



(III) (IV)

$R = CH_3-CH=C(CH_3)-CO$.

EXPERIMENTAL

The alkaloid macrophylline was isolated from the above-ground parts of large-leaved groundsel by extraction with dichloroethane.* The preparation of hydromacrophylline has been described previously [1].

Preparation of desoxychlorohydromacrophylline. To 5 g of hydromacrophylline in 25 ml of anhydrous $CHCl_3$ was added 15 g of $SOCl_2$ dropwise. The reaction flask was cooled externally with ice. After the $SOCl_2$ had been added, the mixture was boiled for 1 hour. The $CHCl_3$ and excess $SOCl_2$ were removed in vacuum. The residue in the flask was mixed with ice water. The acid solution was extracted with ether. The residue was made alkaline with 40% NaOH solution and extracted with ether. The extract was dried over Na_2SO_4 and the ether removed to yield 5.1 g of a brown liquid.

After distillation in vacuum at 134-135° (3 mm), the desoxychlorohydromacrophylline appeared as a mobile colorless liquid with $[\alpha]^{23}D - 2.93°$ (c = 7.49, alcohol), R_f 0.78 (ascending, butanol – CH_3COOH – water system).

Found %: C 59.88; H 8.65; N 5.37; Cl 13.82. $C_{13}H_{22}O_2NCl$. Calculated %: C 60.11; H 8.48; N 5.39; Cl 13.68.

The picrate was prepared in alcohol solution. The m. p. was 155-156° (from alcohol).

Found %: N 11.54; Cl 7.58. $C_{13}H_{22}O_2NCl \cdot C_6H_3O_7N_3$. Calculated %: N 11.26; Cl 7.26.

Reduction of desoxychlorohydromacrophylline. A mixture of 5 g of the chloro derivative, 300 ml of distilled isoamyl alcohol, and 16 g of metallic sodium was boiled under reflux for 2 hours. When the whole of the sodium had reacted, the mixture was cooled and carefully acidified to Congo with 10% hydrochloric acid. The isoamyl alcohol was steam distilled from the acid solution and the residue cooled, filtered, made alkaline with 40% NaOH solution, and extracted with ether and then chloroform. From the ether we obtained 1.56 g of a colorless oil with a strong smell of base and from the chloroform, 0.47 g. The total yield was 68.8%. Vacuum distillation yielded a thick, colorless oil with $[\alpha]^{20}D + 19.75°$ (c = 4.07, alcohol); R_f 0.19 (ascending, butanol – acetic acid – water system), and the composition $C_8H_{15}ON$.

The picrolonate was prepared in alcohol solution and had m. p. 180-182° after two recrystallizations from alcohol. It did not depress the melting point of authentic laburnine picrolonate.

* We have now isolated macrophylline from the Caucasian plant Senecio amphibolus also. After vacuum distillation and two subsequent recrystallizations from ligroin (b. p. up to 60°), the macrophylline had a melting point of 50-52° instead of 42-44°.

The picrate was prepared in alcohol solution and precipitated on standing and rubbing with a rod; it had m. p. 171-172° (alcohol).

The methiodide was prepared by boiling a methanol solution of the alkaloid with methyl iodide. Crystals were obtained after removal of the solvent in vacuum and recrystallization of the residue from anhydrous alcohol. The m. p. was 292-294° (Kōfler block).

SUMMARY

1. It was established that macrophylline is an alkaloid of the D-pseudoheliotridane group and is the second (after laburnine) representative of this series isolated from plants.

2. Structural formulas are proposed for macrophylline and macronecine.

LITERATURE CITED

[1] A. V. Danilova, L. M. Utkin, and P. S. Massagetov, Zhur. Obshchei Khim. 25, 831 (1955).*

[2] Galinovsky and Holdberger, Monatsh. 80, 550 (1949).

[3] A. S. Labenskii, N. A. Serova, and G. P. Men'shikov, Doklady Akad. Nauk SSSR 88, 467 (1953).

[4] Adams and Hamlin, J. Am. Chem. Soc. 64, 2597 (1942).

[5] A. S. Labenskii and G. P. Men'shikov, Zhur. Obshchei Khim. 18, 1836 (1948).

[6] G. P. Men'shikov, Zhur. Obshchei Khim. 16, 1311 (1946).

[7] G. P. Men'shikov and G. M. Borodina, Zhur. Obshchei Khim. 15, 225 (1945).

[8] G. P. Men'shikov, Zhur. Obshchei Khim. 23, 1138 (1953).*

[9] L. Culvenor and L. W. Smith, Austral. J. Chem. 10, 464 (1957).

* Original Russian pagination. See C. B. translation.

ALKALOIDS OF THE PLANT SOPHORA GRIFFITHII

A. P. Yakovleva and P. S. Massagetov

S. Ordzhonikidze All-Union Chemicopharmaceutical Scientific Research Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 348-349, January, 1960

Original article submitted December 26, 1958

The bean family (Leguminosae) are a group of plants which are rich in alkaloid-bearing representatives. In the present article, we report the results we obtained on investigating the plant Sophora griffithii, which grows in Central Asia and which has not been studied chemically before.

The material with which we worked was found by one of us (P. S. Massagetov) downstream on the River Naryn and consisted of young twigs and leaves.

The alkaloids were isolated by the usual methods, namely, extraction of the bases with dichloroethane from the plants moistened with aqueous ammonia. When the extraction was made, it was found that this plant is very rich in alkaloids; altogether ether and chloroform extraction yielded a weight of alkaloids representing 3.5% of the weight of dry plant. From the total bases we isolated two alkaloids. The first (a liquid) was obtained from the ether fraction. The amount of it represented 1.4% of the weight of plant material taken. This alkaloid was found to be identical with pachycarpine, which was first isolated from Sophora pachycarpa [1], and then from leaves of Thermopsis lanceolata [2]. In addition, it is also present in other plants (Cytisus caucasicas, Ammodendron conollyi) [3].

The second alkaloid was obtained from the chloroform fraction in an amount representing 0.13% of the weight of plant material. It was a readily crystallizable base whose properties and constants coincided with those of the previously discovered alkaloid cytisine [1]. The identity of these substances was confirmed by direct comparison of the base we isolated with cytisine obtained from Thermopsis lanceolata.

Examination of the mother liquors, obtained after isolation of pachycarpine and cytisine, by means of paper chromatography showed that they contained traces of two more bases with R_f 0.35 and 0.26, corresponding to matrine and sophoramine. (Paper No. 4 was used for chromatography; the solvent was the upper phase of a butanol – water – acetic acid mixture in a ratio of 50 : 50 : 1; the chromatograms were run for about 18 hours at a temperature of 18-20°; the developer was Dragendorf's solution.) The low content of these alkaloids in the mother solutions made it impossible to isolate them from the tarry residues.

EXPERIMENTAL

Isolation of alkaloids. The dry, powdered, above-ground parts (14 kg) were moistened with 8% aqueous ammonia and extracted with dichloroethane. The alkaloids were extracted from the dichloroethane extract with 10% sulfuric acid. The acid extracts were made alkaline with ammonia and extracted first with ether and then with chloroform.

Treatment of ether fraction. The total alkaloids from the ether (309 g) were vacuum distilled. The low-boiling fraction (202 g) with b. p. 138-139° (2 mm) had a rotation $[\alpha]^{18}D + 16.3°$ (c = 9.0; alcohol); the alkaloid monohydroiodide had m. p. 234-235°; the dihydroiodide had m. p. 255-257°; the picrate had m. p.

199-201°. These constants correspond to those of pachycarpine. Mixtures of these salts with corresponding salts of pachycarpine, obtained previously, melted without depression.

Treatment of chloroform fraction. Removal of the chloroform yielded 178 g of noncrystalline bases. Trituration with acetone yielded crystals, which, after two recrystallizations from acetone, had m. p. 151-153° and $[\alpha]^{18}D$ − 119° (c = 0.6; water). The yield was 18 g. The constants coincide with those reported previously for cytisine; a mixture of our base with cytisine, which we had at our disposal, melted without depression.

SUMMARY

The above-ground parts of Sophora graffithii yielded 1.4% of pachycarpine and 0.13% of cytisine.

LITERATURE CITED

[1] A. P. Orekhov, M. S. Rabinovich, and R. A. Konovalova, Khim. Farm. Prom. 3, 5 (1934).

[2] A. Orekhov, S. Norkina, and E. Gurevich, Ber. 66, 625 (1933).

[3] A. P. Orechov and N. Proskurnina, Ber. 68, 1807 (1935).

LETTERS TO THE EDITOR

ISOMERIZATION OF A SECONDARY-TERTIARY ACETYLENE α-GLYCOL TO A SUBSTITUTED β-FURANONE

V. M. Al'bitskaya and É. D. Venus-Danilova

Lensovet Leningrad Technological Institute

Translated from: Zhurnal Obshchei Khimii, Vol. 30, No. 1, pp. 349-350, January, 1960

Original article submitted October 3, 1959

The secondary-tertiary α-glycols of the acetylene series which we investigated previously were converted into substituted furans by the action of mercuric chloride [1]. Nonetheless, the products formed by heating 3-methyl-5-phenylpentyn-4-diol-2,3 (I) with 20-30% sulfuric acid were found to contain 2,3-dimethyl-5-phenylfuranone-4 (III) in equilibrium with its enol form (II).

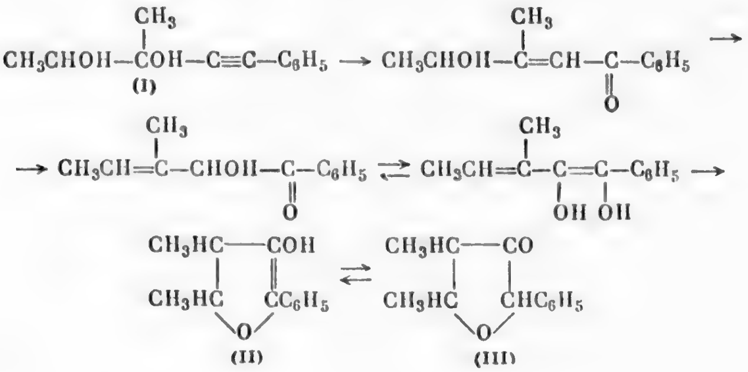
B. p. 138-138.5° (4 mm), M 199.6, 188.9 (calc. 190); $n^{20}D$ 1.5360; 81% enol.

The semicarbazone had m. p. 116-117° (from aqueous alcohol).

Found %: C 63.32; H 7.03; N 17.21. $C_{13}H_{17}O_2N_3$. Calculated %: C 63.16; H 6.88; N 17.00.

The furanone was characterized by the infrared spectrum. It was found to contain absorption bands of carbonyl (1709 cm^{-1}), a double bond (1623 cm^{-1}), an ether oxygen in a tetrahydrofuran ring (1073 cm^{-1}), and a hydroxyl (3440 cm^{-1}) [2].

The isomerization of the glycol into the furanone may be represented in the following way:



It should be noted that β-furanones have been obtained previously by isomerization of some oxides of the acetylene and vinylacetylene series [3].

LITERATURE CITED

[1] É. D. Venus-Danilova and V. M. Al'bitskaya, Zhur. Obshchei Khim. 22, 816, 1568 (1952).*

[2] Application of Spectroscopy in Chemistry [Russian translation] (Foreign Lit. Press, 1959).

[3] F. Ya. Perveev and N. I. Kudryashova, Zhur. Obshchei Khim. 24, 1375 (1954).*

* Original Russian pagination. See C. B. translation.

SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR.
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosenergoizdat	State Power Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LEIIZhT	Leningrad Power Inst. of Railroad Engineering
LET	Leningrad Elec. Engr. School
LETI	Leningrad Electrotechnical Inst.
LETIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MEP	Ministry of Electrical Industry
MES	Ministry of Electrical Power Plants
MESEP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTI	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.-Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOE	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIEL	Central Scientific Research Elec. Engr. Lab.
TsNIEL-MES	Central Scientific Research Elec. Engr. Lab.—Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIESKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Metrology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZEI	All-Union Power Correspondence Inst.

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us. — Publisher.